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Fenco Shawinigan Engineering

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BY

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HALIFAX, NOVA SCOTIA

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1.0

INTRODUCTION

Fenco Shawinigan Engineering Ltd. was selected by Supply and Services Canada to conduct a study of the Nova Scotia silica industry.

The study was carried out under the Nova Scotia/Canada Mineral Development Agreement, and as part of CANMET's larger study of silica resources in Canada.

Five deposits of silica, situated in various areas of the Province of Nova Scotia, have been subjected to detailed study. All the sites have been visited, and existing information and reports gathered and used as the basis for the study. Other materials and papers, related to the beneficiation of silica sands, have been collected and reviewed as an additional basis for discussion and recommendations concerning future process development testwork.

The main part of this report is a summary of the data, particularly from the point of view of the future production of quality silica sand. The emphasis in the conclusions is placed on the processing, economics and potential of individual deposits. The market aspect is considered only in general terms.

2.0 SUMMARY2.1 Silica Deposits List

Table 1 lists the Nova Scotia deposits of silica visited and included in this study.

TABLE 1

<u>Location</u>	<u>Owner</u>	<u>Present Status</u>
Brazil Lake	N.S. Sand & Gravel	In operation
Belmont	N.S. Sand & Gravel	Intermittent operation
Cheggoggin Point	Scotsville Mineral Resources	Old quarry; plans for sampling.
Diogenes Brook	Recently tendered, ownership not declared.	Old workings; recently sampled.
Elmsvale	N.S. Sand & Gravel	Old pit; bulk sampling planned

2.2 Information Sources

All the silica deposits listed above have been visited. The locations, access, reserves, and present operating status have been described. Additional information has been assembled from the Nova Scotia Department of Mines and Energy files. This data includes past development testwork and results as well as the past operating and some market discussions.

All the referenced reports are included in the appendix to this study.

2.3 Data Search

A computer data search was conducted for papers on the beneficiation of silica sands. A number of good articles were found, studied and used in the recommendations section of this report. These are also included in the appendix to this study.

2.4 Process Development

A relatively large volume of beneficiation testwork has been performed in the past on Nova Scotia silica deposits. This work is described and commented further upon in this study, but in the summary it is noted that most of the development work was carried out from 15 to 55 years ago. It is therefore concluded that more up-to-date testing methods and process technology should be investigated.

Apart from such basic grades as presently produced, e.g. blast sand and filter sand, the recovery of the higher grade products should be investigated. This investigation should be based on a thorough study of existing and potential markets, and it should employ various beneficiation methods including hot and cold acid leach, magnetic separation, gravity concentration and flotation. Efforts should be concentrated on the production of the grades indicated and recommended by the market study.

The economic evaluation of the testwork results will then allow assessment of the viability of the approach taken and the results obtained.

2.5

Production Market

Silica sand is a low price commodity and therefore producers can profitably serve only local markets. Traditionally, Nova Scotia sand producers supply consumers in the Maritime provinces and in New England states and it is this area that is of principal interest in relation to the subject of this study.

Present day production of various grades of silica sand within the Province of Nova Scotia is limited to the activities of Nova Scotia Sand and Gravel Limited. Their principal operation is at Nine Mile River, also known as Brazil Lake mine, with periodic mining at Belmont. The main product is blasting sand; foundry sand, filter sand and glass sand account for the balance of tonnage sold.

Nova Scotia Sand and Gravel Limited serves the Maritime market and the Province of Quebec.

3.0 NOVA SCOTIA SILICA DEPOSITS

This section contains detailed descriptions of all the deposits under study. Each description includes geography, geology, reserves, recent status, operation, production and market served (if any). It also provides a more detailed discussion on past and recommended future beneficiation testwork.

3.1 Brazil Lake (Nine Mile River)

3.1.1 Ownership

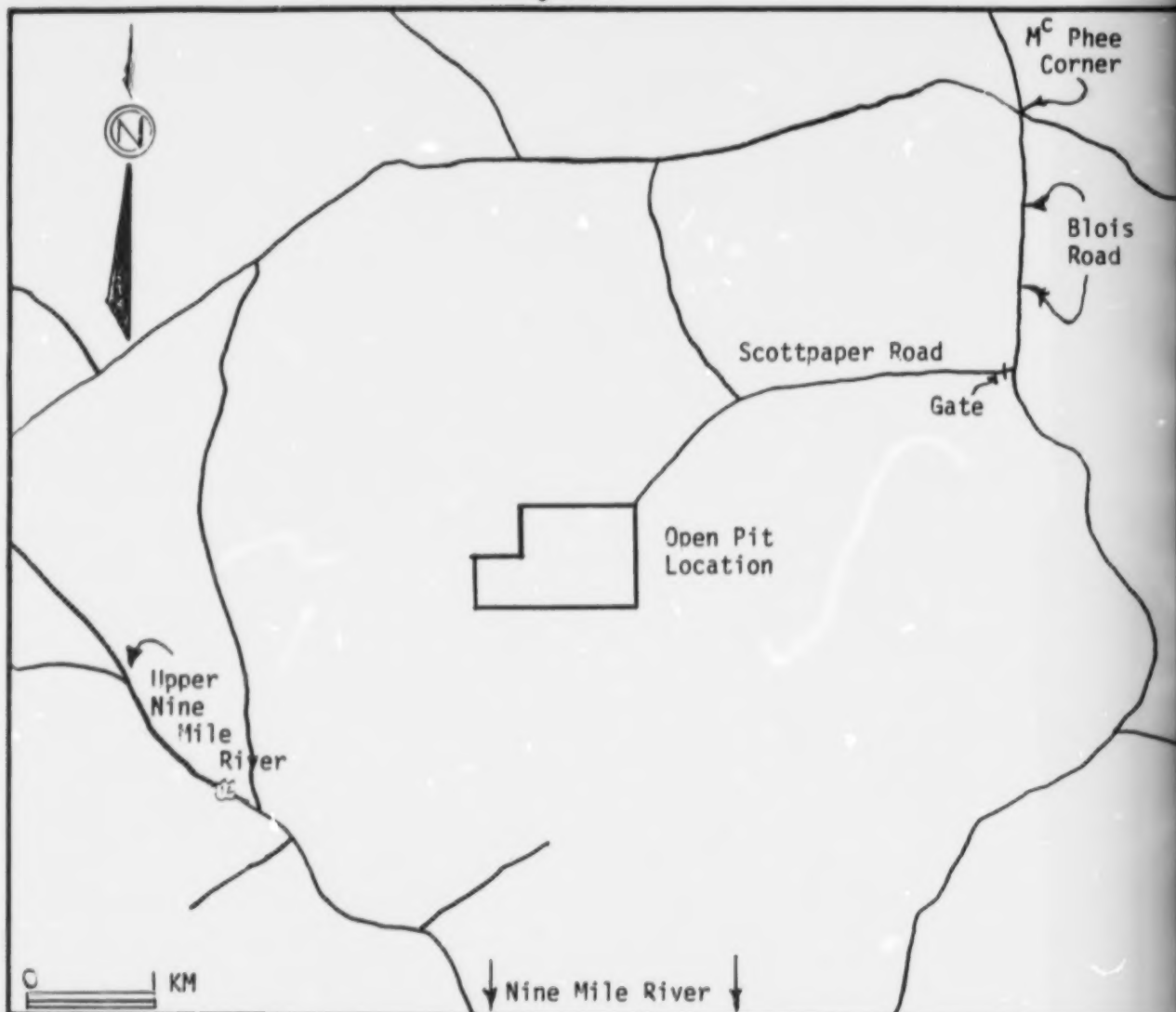
Nova Scotia Sand and Gravel Limited, Mr. Bordon MacLellan, Manager.

3.1.2 Location and Access

Nova Scotia Sand and Gravel Limited has a group of five claims (81 Ha) approximately 4 km due north of Nine Mile River in Hants County. The site is accessed from McPhees Corner by driving south 2 km along the Bois Road, then turning west 3.8 km along the Scott Paper Company road. Refer map on page 6.

3.1.3 Site Description

The site now contains a 3 hectare open pit measuring 300 m long in a figure "8" configuration. It is partially water filled. Overburden, varying from 2 to 10 m, was stripped from the pit ore and stockpiled in waste dumps. Including dumps, open pit and clear cut areas, the prepared site totals some 8 hectares in area. Adjacent properties, some of which are privately owned, have 20 to 25 m thickness of overburden, with mixed forest and swampland. These factors may restrict future expansion. Refer photographs on page 7.



Location Plan

Nine Mile River Silica Deposit
 M^cPhees Corner Hants Co. Nova Scotia

GEOCON INC.

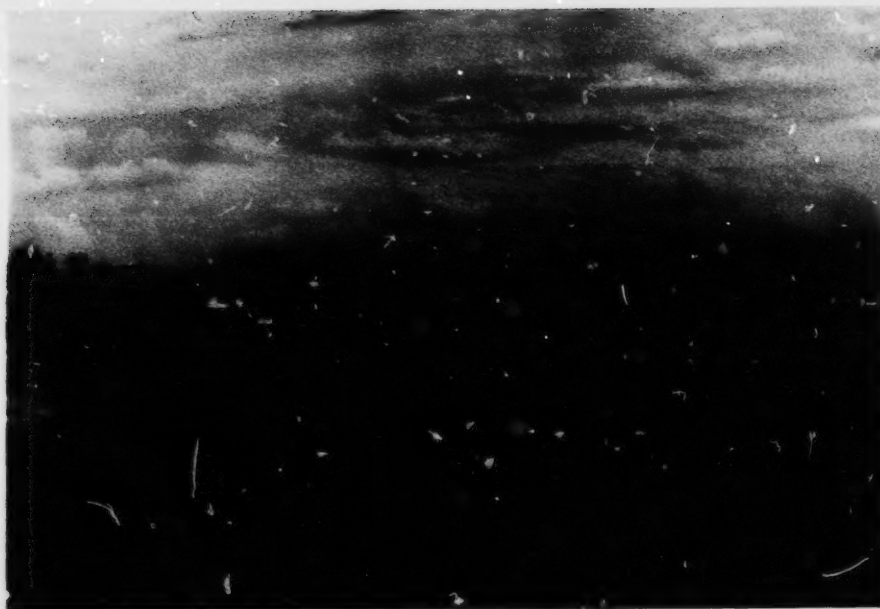
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Stockpiles and ramps down to open pit, looking southeast at east end of pit.



Overburden and silica sand exposed in west end of pit, looking southwest.

3.1.4 Deposit Description

Stea and Fowler (1981)⁽¹⁾ provide a good description of this site. Briefly, it is a Cretaceous Age fluvial deposit with interbedded sediments grading from whitish sandy cobbles to pinkish sandy mud. Black and red staining are visible in the sand fractions.

Quartz represents 98 percent of all the minerals observed in tests conducted for the N.S. Department of Mines and Energy. Kaolinitic clay and mica, feldspars (less than 1 percent) and heavy minerals (0.3 to 2.9 percent, including ilmenite, hematite, staurolite, zircon, tourmaline) are present in small amounts.

The quartz may occur as single or composite grains. Grains are generally subrounded to angular.

These Cretaceous Age sediments unconformably overlie the Windsor Group Carboniferous Age sediments and unconformably underlie Pleistocene glacial sediments. The thickness of the silica sediments, encountered to depths of 30 m below the ground surface, ranges from 12 to 23 m in selected boreholes.

3.1.5 Development History

The deposit was initially discovered under a surface covering of sphagnum moss in 1976 during construction of a woods road. Its location was brought to the attention of Nova Scotia Sand and Gravel Limited who drilled the deposit in the summers of 1977 to 1979. Drilling was carried out on a grid pattern to what was considered the economic limits. Commercial production began in 1979 with the removal of 112,000 tons and an additional 41,400 tons in 1984. Between operations the pit was allowed to flood.

3.1.6 Silica Quality

As mentioned above the deposit runs approximately 98 percent quartz⁽²⁾.

3.1.7 Reserves

Exploration drilling conducted between 1977 and 1979 defined probable reserves of approximately 1 million tons; this has since been depleted by some 300,000 tons.

3.1.8 Production, Treatment

Pit run silica is trucked to the plant as required from the Nine Mile River deposit. Treatment is by washing and hydro separation with minus 100 mesh fines removed and presently stockpiled for lack of a market. The coarse fraction is dried and sieved according to market requirements.

Drying is conducted in an oil fired Starnel fluid-bed drier (\$500,000). The product is shipped in bulk or bag. No crushing is conducted although Nova Scotia Sand and Gravel Limited has a \$100,000 crusher available.

Refer to page 39 for photographs of the plant.

3.1.9 Products, Markets

At present, approximately 25,000 tons per annum are produced for blast sand of which Nova Scotia Sand and Gravel Limited supplies 90 to 95 percent of the Atlantic Province requirements. Approximately 1,000 tons of foundry sand are produced annually, primarily for Industrial Marine Products, Dartmouth, N.S. and Breton Industrial and Marine Ltd., Port Hawkesbury, N.S. As well, nursery

sand is produced for various greenhouses, and filter sand is produced occasionally for supply to newly-constructed sewage plants. Thus, annual productions may amount to 30,000 tons.

Nova Scotia Sand and Gravel Limited can supply all the silica demands of the Maritime provinces. The Company is market conscious and has carried out investigations in this respect. It is interested in reaching the glass production market and is considering acid leaching as a means of reducing excessive iron content. However, before any decision can be taken, guaranteed sales for the product will be required.

As this is a producing mine, the cost of additional processing facilities, production and sampling will be lower than for other non-producing Nova Scotia silica deposits.

3.1.10 Recommendations

It is understood that a study of silica markets is to be conducted by the Mineral Policy Sector of Energy, Mines and Resources. Should this market study indicate a potential market for glass sand in the Atlantic Provinces it is recommended that a study be conducted to establish the feasibility of supplying this market with material from Brazil Lake.

This feasibility study should include a review of:

- the available reserves of silica material for glass manufacture,
- the beneficiation requirements to meet glass sand specifications,
- the economics of production expansion of the existing processing facilities.

3.2 Belmont

3.2.1 Ownership

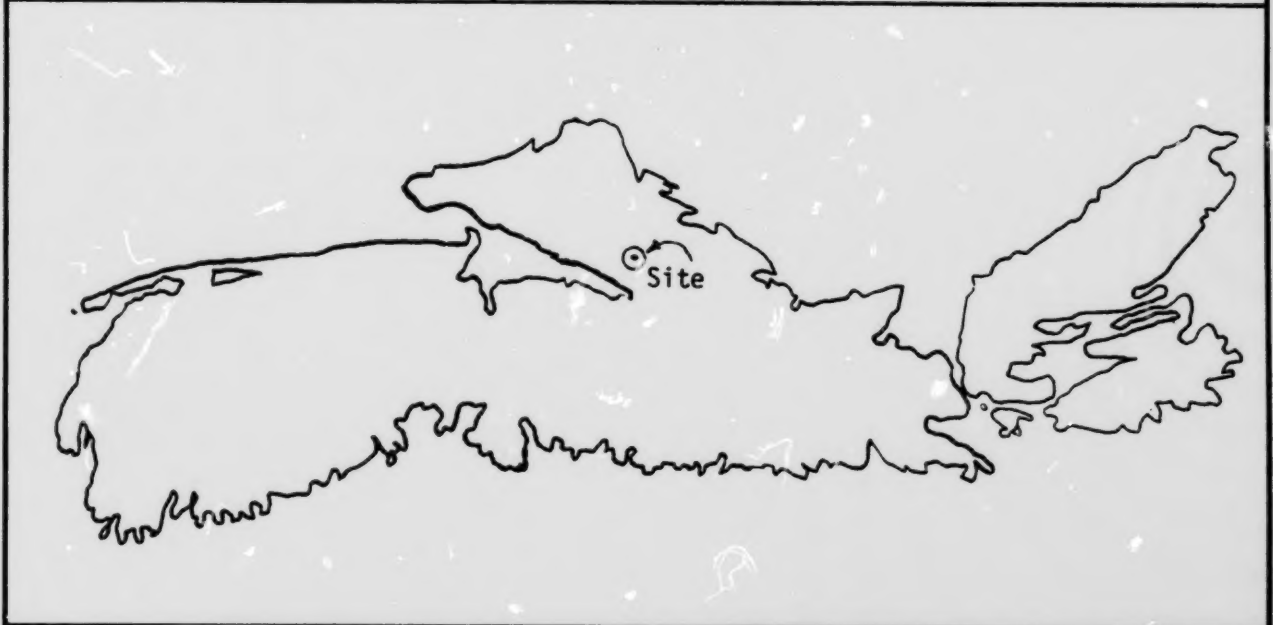
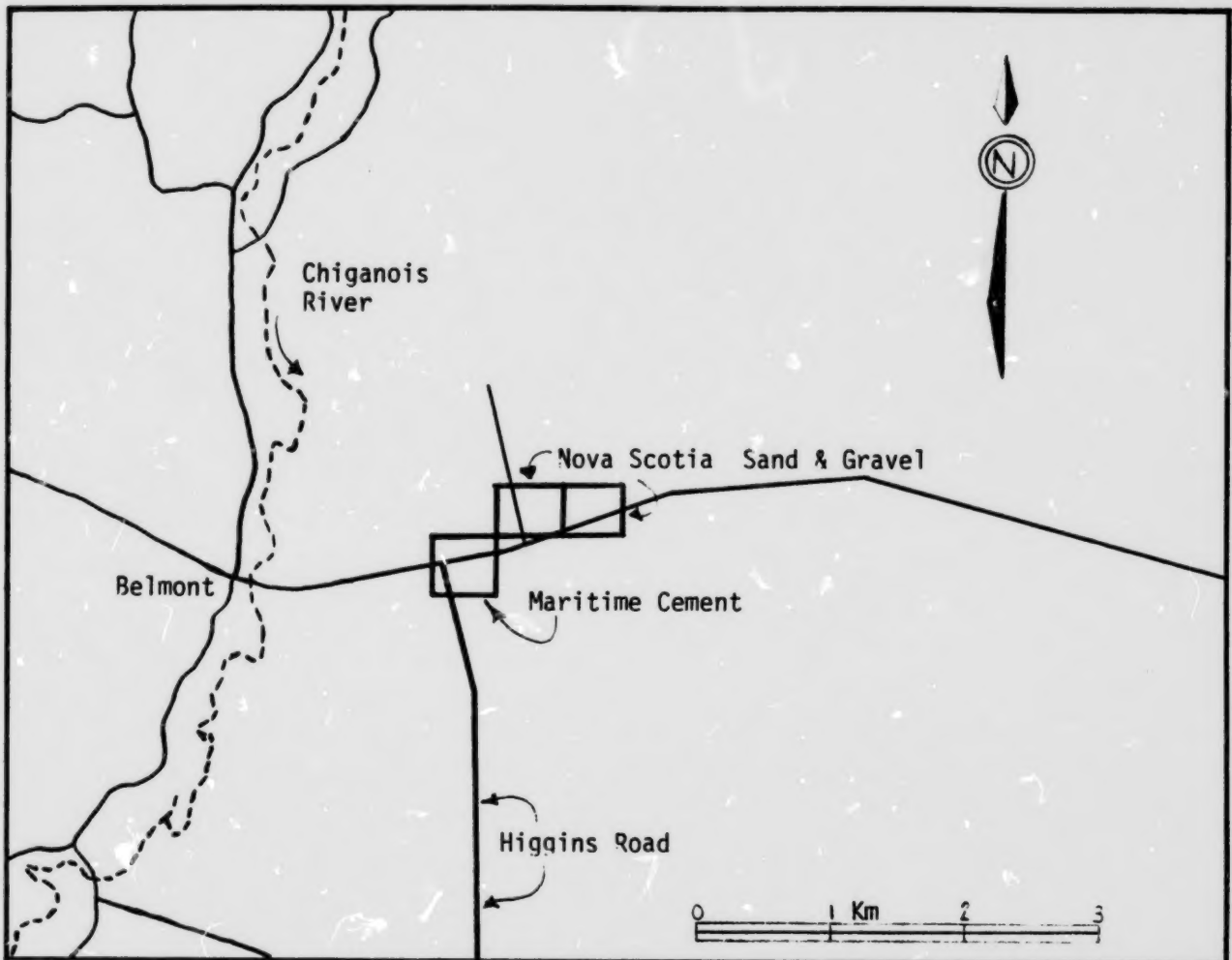
Two mining claims are held by Nova Scotia Sand and Gravel Limited, Mr. Borden MacLellan, Manager. One mining claim is held by Maritime Cement, Mr. Don King, Manager of the Brookfield Operation.

3.2.2 Location and Access

This deposit is located approximately 10 km northwest of the town of Truro in Colchester County, Nova Scotia. Access is from the Debert Exit from Route 102 west of Truro to the Town of Belmont. The Maritime Cement deposit is exposed 2.0 km east of Belmont in a cleared area just south of the road; the Nova Scotia Sand and Gravel pit lies 2.5 km east of Belmont in a cleared area to the north of the road as shown on the map on page 12.

3.2.3 Description

The eastern most pit is approximately 10 m lower in elevation than the western pit and is water filled with the water table standing 1 to 1½ m below ground level. Several hundred tons of unprocessed silica sand have been stockpiled around the pit. This stockpile has been washed white at the surface. There are no signs of recent activity. The western most site south of the highway has signs of more recent activity. Ground water was not observed in the shallow but wide-spread excavation. Some material is stockpiled at this location as well. Refer photograph on page 13.



Location Plan

Belmont Silica Deposit
Colchester Co. Nova Scotia

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Stockpile and open pit, looking north at Nova Scotia Sand and Gravel deposit.

3.2.4 Development History

The pit operated by Nova Scotia Sand and Gravel on the north side of the road was opened in the late 1920's. Since then the pit has been extended to a little more than one-half a hectare in area, depth unknown. The pit has not been used in the last 10 years to any extent. The silica from the Maritime Cement pit is used occasionally for making high silica cement at their Havelock facility in New Brunswick, but the quantity used is small.

3.2.5 Silica Quality

The sand consists of well rounded, clear to frosted quartz with increasing amounts of subangular grains in the finer size range. The sand is fine grained with sizes predominantly between the No. 30 and 200 mesh sizes, with from 1 to 12 percent passing the 200 sieve. On drying, the natural material exhibits a low bond strength and a bulk density of 1600 Kg/m³ (100 pcf). One analysis provides the following composition:

	<u>Wt. %</u>
SiO ₂	90.50
Al ₂ O ₃ +TiO ₂	4.21
Fe ₂ O ₃	1.52
CaO+MgO	1.46
Na ₂ O	0.10
LOI @ 1050°C	1.69

3.2.6 Reserves

The only estimate for reserves refers to the Nova Scotia Sand and Gravel pit as having 50,000 tons of silica sand.

3.2.7 Production, Products, Markets

Belmont mine is operated only intermittently, according to demand. Some 15 years ago it supplied a limited amount of silica sand to Maritime Cement for the production of special clinker. Prior to 1978 blasting sand was supplied to Canada Cement.

3.2.8 Recommendations

There is no active mining at Belmont at the present time. In his report, A.E. Cameron⁽⁴⁾ states that the economic value of the deposit is unclear. Rather high iron and titanium oxides content⁽⁵⁾ make this sand unsuitable as a glass making product, but some indications suggest that a moulding sand could be produced.

Low reserves and a lack of high quality material make this deposit the least economically interesting of the five sources studied.

3.3 Cheggoggin Point

3.3.1 Ownership

Mineral rights are presently held by Scotsville Mineral Resources, Halifax, N.S., Mr. Robert Patterson, President.

3.3.2 Location and Access

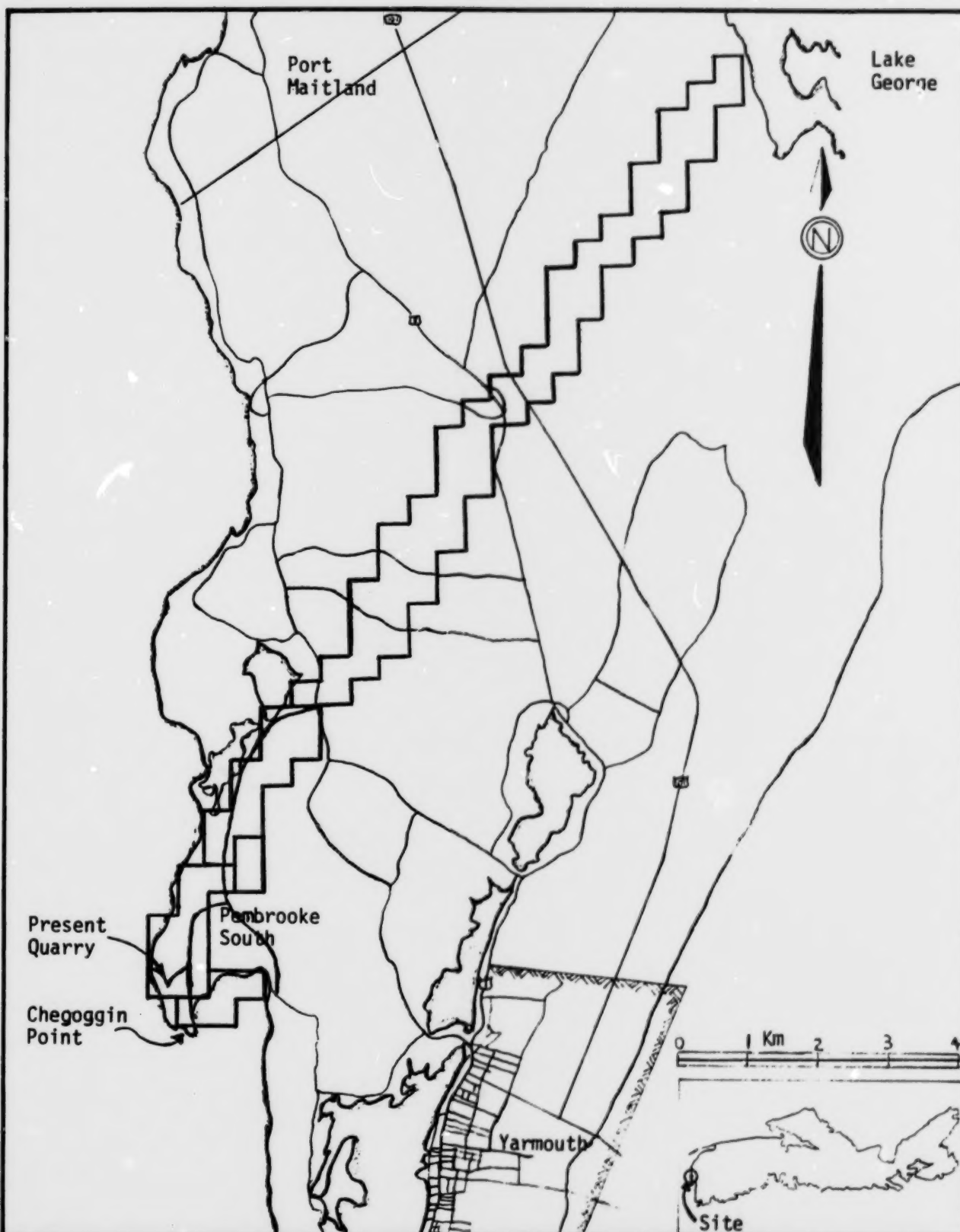
The deposit lies to the north and west of the town of Yarmouth. The deposit extends from the Atlantic Ocean inland for an estimated 18 km striking N 20° to 30° E, to the vicinity of Lake George.

The map on page 17 indicates the open pit and current mining claims. Access is via the shore road to Cheggoggin Point and the quarry and by numerous other roads in this area which cross the strike of the deposit.

3.3.3 Deposit Description

Bedrock consists of tightly folded Upper Cambrian to Silurian Age sedimentary rocks striking predominantly N 20° to 30° E. The oldest rocks are slates and minor argillites of the Halifax Formation which are conformably overlain by quartzites with minor slates, andesites, and amphibolite - feldspar gneisses of the White Rock Formation.

It is the quartzites of the White Rock Formation which are of interest for silica production, particularly the limb of a syncline with its axis running through Yarmouth Harbour. Refer photograph on page 18.



Location Plan

Cheqoggin Point-Lake George Quartzite Deposit

Yarmouth Co. Nova Scotia

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North end of quarry, stockpile in foreground and sea in background, looking north.

The quartzite outcrops at several locations, most notably in a 70 m thick broken section on the beach at Chegoggin Point where it is interbedded with slate and amphibolite. The existing quarry, just inland from the beach, is flooded and the quarry floor rock was not observed. Additional exposures occur inland near Foote Corner and along a road cut near Lake George.

In general the quartzite is massive with scattered grains of pyrite. It is derived from quartz and cemented with secondary silica and recrystallized. It is faintly laminated.

Thickness of the deposit varies from 25 to 90 m.

3.3.4 Site Description

The existing quarry extends for 390 m along the strike of the White Rock Formation starting 30 m inland from the beach. Width of the opening varies from 20 to 40 m. The quarry is presently flooded and the depth was not determined. The area is generally flat to gently rolling with a cover of glacial soil and dense alder thicket. Numerous chunks of quartzite and bedrock occur in spoil piles and in the disturbed ground associated with the old mine workings.

3.3.5 Development History

The quarry was initially developed by Dosco (Dominion Steel Company) as a source of silica for production of silica brick for refractory use in their Sydney iron mills. During their period of operation Dosco mined approximately 1500 tons per year.

During the 1960's, diamond drilling, geological and geophysical (magnetometer) surveys were carried out over this deposit between

Cheggogin Point and Lake George by Nova Scotia Department of Mines and Energy, by Behre Dolbear & Company Inc., and by Keevil Mining Group Limited.

The mineral rights are now held by Scotsville Mineral Resources. The company is planning a drilling and trenching program to delineate area of high grade silica within the White Rock Formation.

3.3.6 Silica Quality

From analyses of samples from available drill core the silica content (SiO_2) ranges from 84 to 99.2 percent averaging 98.5 percent over a 50 m thickness in one borehole. Iron content ranges from 0.3 to 3.5 percent, alumina (Al_2O_3) from 0.09 to 0.86 percent, CaO and MgO a maximum of 0.21 percent and 0.56 percent respectively. Other measured trace minerals include titanium, sodium, and potassium, all being less than 0.1 of a percent.

3.3.7 Reserves

Reserve calculations are based on the results of the three bedrock exposures and three diamond drill holes. Behre Dolbear and Company Inc. attached a fair degree of confidence to an estimate of 245,000 tons based on a length of 85 m, a width of 64 m and a depth of 15 m. Based on the full 18 km length between Cheggogin Point and Lake George, with an assumed average width and depth of 30 and 15 m respectively, reserves of 20 million tons can be postulated.

3.3.8 Process Development Work

A substantial amount of drilling, sampling and metallurgical test-work has been carried out in the past, mainly in the 1960's. The high grade of silica rock found in the deposit, together with potentially large reserves, make this ore body particularly attractive.

The testing programme performed by the Lakefield Laboratories in 1968-69⁽⁶⁾ included crushing, grinding and desliming followed by flotation and magnetic separation. The principal objective of this work was to determine whether the iron oxide content in the -35 + 150 mesh size fraction could be reduced to a maximum value of 0.04 percent to meet glass sand specifications.

Two composite samples were prepared, crushed to minus 28 mesh and the fines (minus 150 mesh) removed. Next, high intensity magnetic separation was employed to remove the majority of iron-bearing particles, followed by desliming and flotation steps. As the flotation tails contained 0.19 percent iron oxide, additional cleaning was carried out with an iso-dynamic separator resulting in a final product still assaying 0.10 percent Fe_2O_3 .

Although the original testwork target of 0.04 percent Fe_2O_3 had not been achieved, the product, with 0.10 percent Fe_2O_3 , was well within the limits of coloured glass specification.

3.3.9 Sampling, Production and Other Data

A study⁽⁷⁾ commissioned by Northern Silica Co. Ltd., New York, N.Y. was carried out by Behre Dolbear & Company Inc. in 1965 to assess the viability of Chegoggin quartz deposit. Preli-

minary calculations of the reserves were made and other factors examined included ore grade, customers requirements and markets.

In the report the author recommends processing testwork to establish whether mine product should be shipped as produced, or upgraded by practical and economical methods to meet the specifications of the glass-making and chemical silica markets.

J.R.M. Dawe, (1968)⁽⁹⁾, briefly describes the deposit and its potential. He states that although the ore cannot be shipped directly for clear glass manufacturing, it could qualify for metallurgical flux usage in the Atlantic coast of U.S. He finds the Chegoggin quartz very attractively located and concludes that it is "probably the closest high grade silica deposit to the largest market in the world, i.e., the Northeastern New England States".

In 1945^(10, 11, 12, 13, 14) quartz outcrop was sampled, analyzed and tested for the production of silica bricks. As the test and analysis results were positive, quartz was mined and supplied to Dominion Steel & Coal Corporation in Sydney N.S. as a raw material for the production of refractories. This operation continued over the years at a level of 1500 tonnes of ore per year.

3.3.10 Recommendations and Comments

Analysis of available data strongly indicates the viability of Chegoggin Point quartz deposit as a prospective ore. Large reserves (estimated at between 7 million and 20 million tonnes), high quality ore and proximity to sea transport and markets, make this deposit potentially the most promising one in Nova Scotia.

At the same time, however, attention is drawn to the fact that the data on product quality and beneficiation characteristics of the ore is very limited. Lakefield Research carried out testwork solely to investigate production of high quality flint glass sand. However, other sources indicate that this material can be used for other end-use products such as:

- Coloured glass
- Silica bricks
- Metallurgical flux
- Chemical silica
- Silicon metal

It is therefore recommended that more thorough process investigation be carried out to provide technological and economic data on the feasibility of production of the above end-use products. Also a fresh approach to high purity glass sand production, including attrition-desliming and leaching will provide more complete and up-to-date information on the possible recovery of high purity sand for clear glass manufacture.

In November/December 1985 a Norwegian firm will be conducting tests on a 10,000 ton sample of Chegoggin Point quartzite to prove its suitability in the manufacture of silicon metal. Should the tests prove successful it is expected that significant quantities of material will be quarried annually for this use.

3.4 Diogenes Brook

3.4.1 Ownership

Mineral rights have recently been tendered by the Nova Scotia Department of Mines and Energy, but as of this writing, the ownership has not been declared.

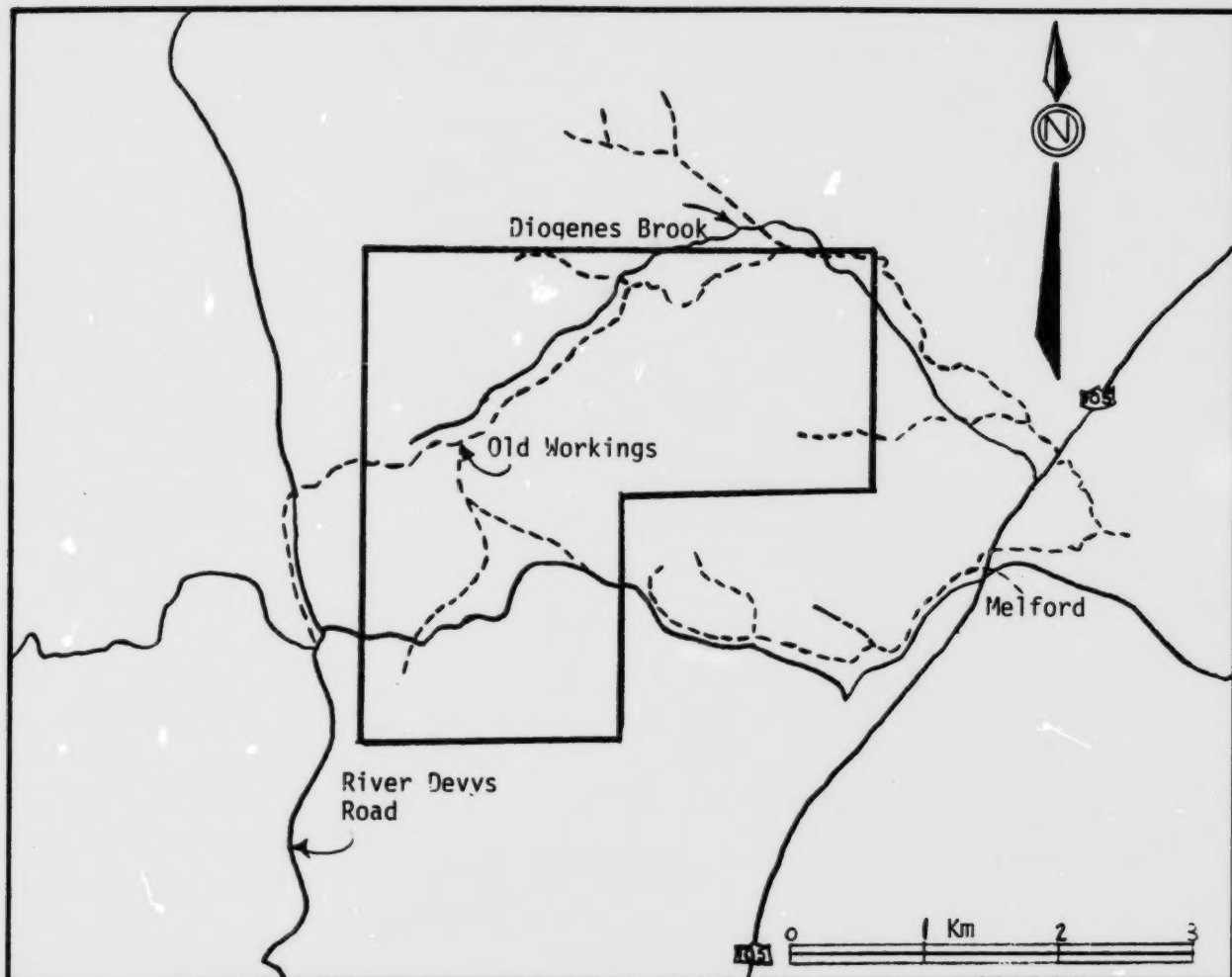
3.4.2 Location and Access

The deposit lies beneath the valley of Diogenes (Glen) Brook approximately 3 km northwest of the village of Melford in Inverness County, Cape Breton, Nova Scotia. Melford is located 32 km east of Port Hastings along Route 105. Access is via route 105 to Melford and by a woods road upstream alongside Diogenes Brook for a distance of 6.4 km. This woods road is passable by automobile for 2 km, and then by a four-wheel-drive vehicle to the site of the old workings, shown on the attached map on page 25.

3.4.3 Deposit Description

The silica sand is situated directly beneath unstratified and heterogenous glacial drift which is thinnest at the valley bottom and becomes thicker uphill. The extent of the deposit is delimited by the presence of bedrock outcrops along certain of its margins. The deposit has been observed to be bedded with beds ranging in thickness from several centimeters to 1 to 2 m. The sand beds are associated with variable amounts of generally grey coloured clay.

The sand beds were observed to slope at about 40 degrees east and in some of the old exposures at up to 70 degrees. The deposit overlies the Mississippian Age Windsor Group and is bounded laterally by the Precambrian George River Group. Refer photograph on page 26.



Location Plan

Diogenes Brook Silica Deposit

Melford Inverness Co. Nova Scotia

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Abandoned pit and borehole location, looking east.

3.4.4 Site Description

The deposit was discovered along the banks of the Diogenes Brook where the glacial overburden had been largely eroded. The flood plain is narrow and the banks are steep and covered with hardwood forest. Relief in the area is up to 75 m. The access road is in remarkably good repair for its 50 plus years' age with washouts at several streams and an occasional fallen tree. The old workings are evident by local depressions and an absence of topsoil. Roadways and the larger clearings still exist but are being reclaimed gradually by the forest.

3.4.5 Development History

The deposit was discovered and at least some work carried out prior to 1911. By 1917, 95 acres of property were taken over by River Denys Sand and Clay Company Limited which began exploitation of both the sand and clay.

During the period 1923 to 1926, approximately 3000 tons were removed by hand and transported along the mine road by 1 ton truck to the railway for shipment. Mining was carried out in open pits with the glacial overburden removed and from lagged tunnels into the valley banks. Some clay was shipped to a pottery firm in Saint John, New Brunswick, while the silica was used as foundry sand by several customers in Nova Scotia.

Recently the Department of Mines and Energy conducted a three drillhole campaign at the property, as a means of measuring reserves, quality and stimulating interest in the deposit. Their report by Dickie is in preparation.

3.4.6 Silica Quality

The silica grains are white to clear, fine-grained, and angular to subrounded. Both varieties become more angular below the 100 mesh size. Silica content (as SiO_2) ranges from 93 to 98 percent, total iron (Fe_2O_3) from 0.4 to 2.4 percent, alumina (Al_2O_3) from 0.75 to 3.2 percent, and titanium from 0.06 to 0.47 percent. Other minerals present in small quantities include muscovite, biotite, feldspars, tourmaline, rutile, magnetite, augite, andalusite, epidote, staurolite, hornblende, zircon and corundum.

3.4.7 Reserves

The recent drilling operations by Mines and Energy has established a reserve estimate of seven million tonnes of silica sand grading over 95 percent SiO_2 .

3.4.8 Process Development Work

The only available data concerning process development work on Diogenes Brook sand deposit dates back to 1930⁽¹⁵⁾. This work was carried out by R. K. Carnochan and its objective was to establish process data for the production of glass sand and blast sand. Two basic samples were treated: a fine lot and a coarse lot. The target value for the glass sand was maximum 0.06 percent Fe_2O_3 plus TiO_2 in size fractions minus 28 to plus 35 mesh and minus 35 to plus 48 mesh.

The principal concentration steps employed were washing, tabling and magnetic separation individually and in various combinations.

In his conclusions the author states that:

1. No glass sand suitable for making clear glass can be obtained from the fine lot.
2. By washing, tabling and screening, about 40 percent of the coarse lot can be recovered as sand suitable for making clear glass.
3. By washing and screening about 76 percent of the coarse lot and 83 percent of the fine lot can be recovered as good blast sand.

3.4.9 Sampling, Production and Other Data

During 1920, when the property was operated by Denys River Sand and Clay Co., the production was sold to Sydney and New Glasgow steel foundries as moulding sand to replace sands previously imported.

At that time, a number of samples were obtained for size and mineralogical evaluation⁽¹⁶⁾. After several stages of agitation and decantation of fines the remaining sand was screened on 10 - 200 mesh sieves while decanted clay was settled and its properties analyzed. The presence of mica was observed in both sand and clay fractions.

In his conclusions the author states that:

1. Sand evaluated under actual working foundry conditions was found to be quite satisfactory and capable of replacing previously imported sands.

2. Clay was found to be perfectly satisfactory for stoneware, Rockingham and yellow-ware.
3. Mica, in more than a very small proportion, is a very undesirable constituent of moulding sand.

Mine production was reported⁽¹⁶⁾ at about 1500 tons per year and was sent directly to the foundries as moulding sand. At the same time, some of the imbedded clay found application in the pottery industry.

Laboratory tests performed on this sand showed "extraordinary refractory power of the sand, while the clay substance extracted from it shows equal refractoriness."⁽¹⁷⁾

3.4.10 Recommendations and Comments

Available records indicate that the Diogenes Brook silica sand deposit has an excellent potential for a producing mine. Proven and possible end-products include:

- Clear glass sand
- Blasting sand
- Moulding sand
- Pottery clay

With the majority of the markets being local, within the Province of Nova Scotia, low transportation costs would give this mine a distinct advantage over imported competing products.

A metallurgical testing program is needed, to update results obtained 55 years ago, to provide process and cost data on the production of various end-products. Available test reports show that certain size fractions of processed sand meet the clear glass sand specifications, while others do not. This work indicates the need for new beneficiation tests whereby the potential for the high quality sand would be investigated and an economically optimized process developed.

The feasibility and economy of the end-products should be investigated more closely using up-to-date methods. The quality of these products would then be used to define the prospective markets. However, the data available indicates that the most likely customer is the Nova Scotia steel industry.

3.5 Elmsvale (Musquodoboit)

3.5.1 Ownership

Mineral rights are presently held by Nova Scotia Sand and Gravel Limited; Mr. Borden MacLellan, Manager.

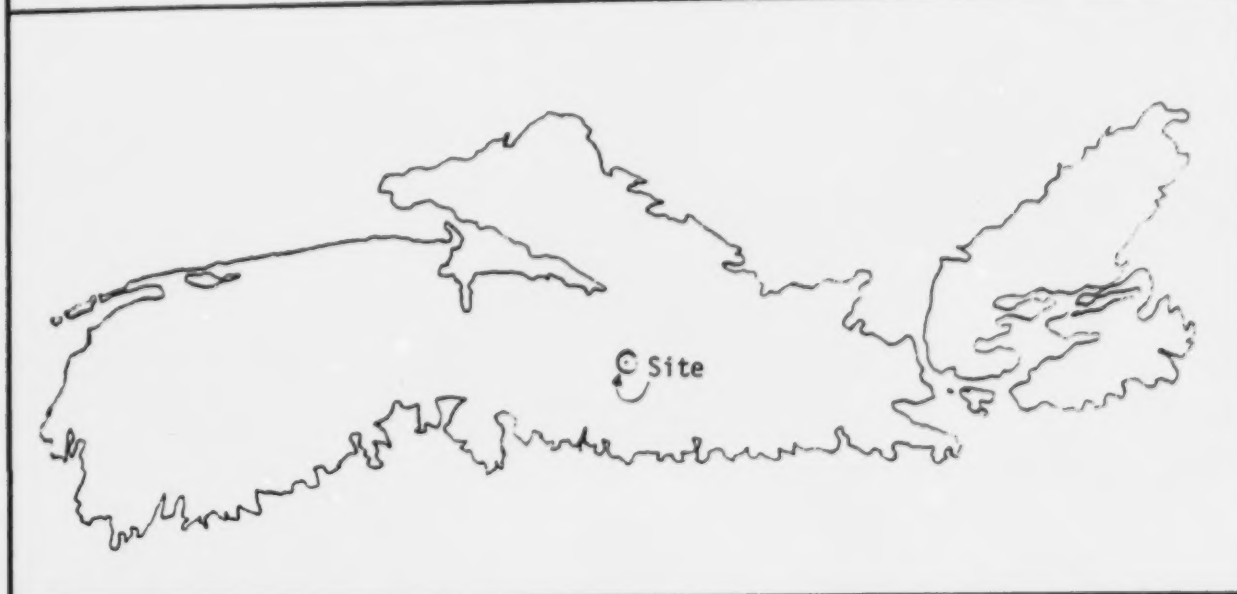
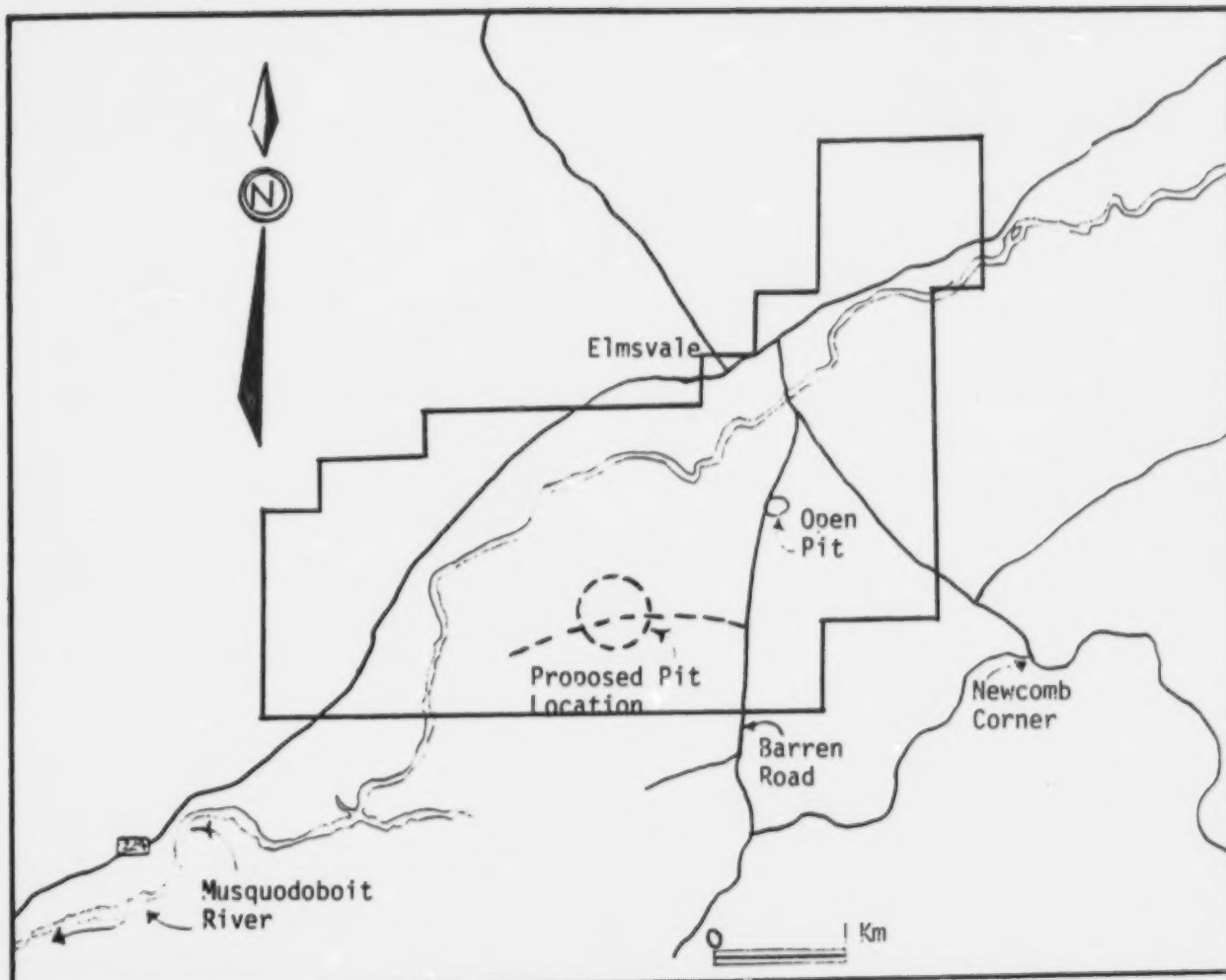
3.5.2 Location and Access

This silica sand deposit is located 1 to 2 km south of Elmsvale or approximately 6½ km northeast of Middle Musquodoboit in Halifax County at Elmsvale and travelling 1 km toward Newcomb Corner, turn right onto the Barren Road and travel 1 km to the location of the first open pit which is now worked out. The site of the future operations is accessed by travelling 0.7 km farther south, then turning west onto a logging road and travelling 0.7 km. Refer to map on page 33.

3.5.3 Site Description

The worked-out pit adjacent to the Barren Road is water filled and located in a flat-lying, clear-cut area. The excavated area measures approximately 200 by 250 m on the east side of the road. A small stockpile of perhaps 50 tons of sand remains. Part of the deposit extends beneath and to the west of the road but this section would not be economic to recover. The site is to be reclaimed by levelling the spoil dumps and reforesting in the near future.

The site for the proposed open pit lies farther to the southwest beneath gently rolling hillside and the flat, low-lying wet terrain at its toe. Most of this site is covered by softwood forest. Refer to photographs on page 34.



Location Plan

Elmsvale Silica Deposits

Elmsvale Halifax Co. Nova Scotia

GEOCON INC.

DATE Aug 2, 85 SCALE N.T.S.

MADE
PGB

CHKD

APPD

NO. F2199-



Worked out pit, looking southeast.



*Closed area at proposed
pit, looking north.*

3.5.4 Deposit Description

These Cretaceous silica deposits are associated with clay, silt, lignite, and concretionary pyrite. They are located between the Villages of Middle Musquodoboit and Central Musquodoboit along the Musquodoboit River Valley. The silica sand is of fluvial origin. A detailed description is given by Fowler (1972)⁽²¹⁾.

Drilling for sand by the Nova Scotia Department of Mines and Energy, and by Nova Scotia Sand and Gravel Limited, was carried out between Elmsvale and the road to Brookvale and defined two economic areas. One of these areas is presently worked out and the other will shortly be opened for bulk sampling.

The newest deposit has been drilled with more than 50 holes using a grid pattern with 30 m spacing along line and generally a 20 m spacing between lines. Representative boreholes indicate that the silica varies in thickness from 7 to 22 m at this location. The silica from this area was grey in color as opposed to the white silica found elsewhere in the Musquodoboit Valley.

3.5.5 Silica Quality

Samples from the drill holes at the proposed pit have generally 98 percent passing the number 8 sieve and from 2 to 60 percent passing the number 200. The silica grains are grey in color and angular to sub-rounded as observed from a small washed sample recovered from a drill site at the proposed pit. At the worked-out pit, the silica is clear or partly iron stained and has a variable clay content and some grains of heavy minerals. Analysis of sand from this old pit indicates the presence of from 0.08 to 0.25 percent Fe_2O_3 , with SiO_2 running from 95.3 to 98.3 percent.

Other analyses of silica sand from the Musquodoboit area show purities from 86 to 98 percent SiO_2 with 0.8 to 6.8 percent iron and 0.6 to 12.8 percent Al_2O_3 after washing.

3.5.6 Reserves

Nova Scotia Sand and Gravel Limited have calculated that 3.5 million tons of silica sand are economically available in the proposed pit area. This result is based on the drilling and sampling conducted to date. A proposed bulk sample will provide additional information on the quality of the silica, on required processing, and potential markets.

3.5.7 Process Development Work

Three beneficiation tests reports^(19, 20, 21) describe relatively recent (1969, 1972) work carried out on the Elmsvale area silica sand and clay samples.

The testwork carried out by A.K. Grice⁽¹⁹⁾ employed washing, sizing and magnetic separation to produce glass sand of acceptable composition. The results obtained were only partly successful as the iron oxide content was still 1.08 percent.

J.D. Wright⁽²⁰⁾ investigated applicability of Elmsvale sand for foundry and other uses. From the screen analyses, the author concludes that the sand in question is unsuitable for foundry use as only 2 percent of the material tested passed the 200 mesh sieve. He admits, however, that his samples were not correctly taken and had considerable contamination.

His further work concentrated on the removal of mica by flotation, using petroleum sulphonate as collector. Although iron-bearing biotite was recovered in the concentrate, most muscovite remained with upgraded silica tails.

In his conclusions J.D. Wright notes that some areas of the deposit contain high grade silica sand, while others would need beneficiation to upgrade the silica for industrial uses. Tests indicate that the silica content can be increased by a water wash, by hydraulic classification or by acid leaching.

Tests indicate that the main impurities are white and brown micas.

J.H. Fowler⁽²¹⁾ concentrated his efforts on beneficiation of clays. This work involved magnetic separation, iron removal by acid leaching and quartz removal by "Beaker Decantation" method. While magnetic separation gave negative results, the hydrochloric acid leach gave a good reduction of iron oxide from 4.83 percent to 0.27 percent, at the same time favourably increasing the pyrometric cone equivalent value from 23 to 31.

Sub-sieve size fractions obtained from the decantation were subjected to differential thermal analysis tests.

Unfired clay was found to have good and very good workability, plasticity and refractory properties. Depending on the origin of the sample very hard and steel-hard hardness was achieved after firing.

3.5.8 Recommendations and Comments

An examination of the available test reports indicates that the Elmsvale deposit can produce a lower grade glass sand and a good grade refractory clay.

However, the declining glass container manufacturing market⁽³²⁾ limits prospects in this area. Therefore products other than amber glass sand should be given additional consideration both during the recommended testing period and during appraisal of the overall economics of the deposit. Should the possibility of the production of refractory clay be a viable one, this avenue will require a more thorough exploration.

To obtain more definite information concerning quality and economic value of the deposit, a thorough and representative sampling program has to be carried out to provide material for metallurgical testing. This testing should then outline the reserves areas capable of producing grades of sand and possibly clay to establish process data for the operator.

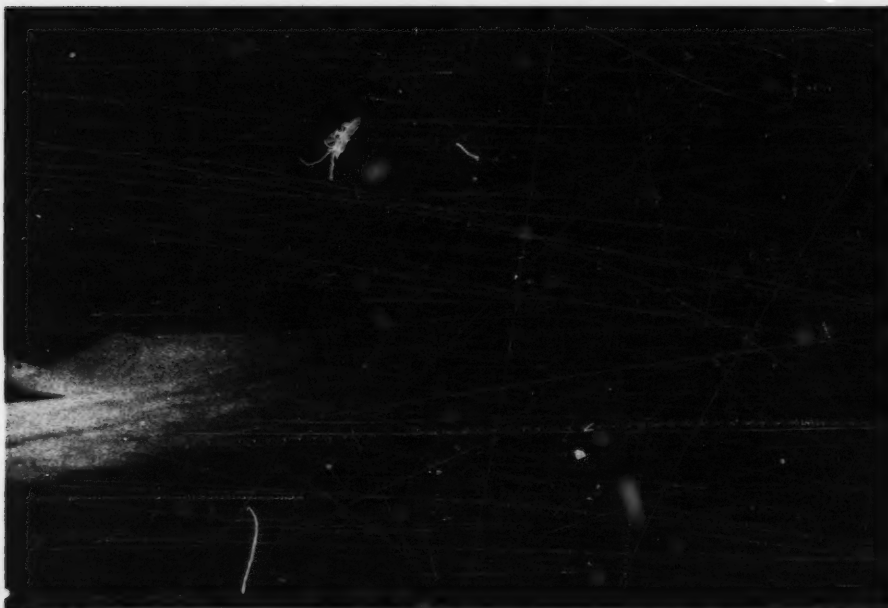
As stated earlier, the area for the proposed open pit will shortly be opened for bulk sampling. It is now recommended that this sampling be carried out with input from a process engineer so as to provide representative material for testwork.

The sand reserves at Elmsvale are 3.5 million tonnes; however this tonnage will be affected by beneficiation process and the end-use product considerations. This deposit will require other favourable factors such as low production costs and close markets to make the operation economically attractive.

NOVA SCOTIA SAND AND GRAVEL PROCESSING FACILITY



Hydro separation plant, raw sand stockpile in right foreground, loading into conveyor at left, hydro separation drum at centre and undersize stockpile to left.



Undersize stockpile.

4.0 GENERAL INFORMATION

4.1 Silica Uses and Specifications (20, 35)

1) Silicon Carbide

Silica sand used for silicon carbide manufacture should have a minimum silica content of 99.25 percent. Lime, magnesia and phosphorus are objectionable. The iron and alumina should be less than 0.1 percent each. A coarse-grained sand is preferred for silicon carbide manufacture, but finer sands are sometimes used. All sand should be plus 100 mesh, with the bulk of it plus 30 mesh in size.

2) Silica Brick

The silica content of the quartz used should be at least 96 to 98 percent. The iron and alumina should be less than 1 percent each with the total less than 1.5 percent. Other impurities, such as lime, alkalis and magnesia, should be low.

Silica brick has a high load bearing capacity at elevated temperatures and consequently has been widely employed for sprung arches used as roofs for open-hearth furnaces, glass tank crowns, ceramic kilns and coke ovens. Fired brick consists of shattered quartz grains that have been almost completely transformed into cristobalite (starting at the edges of the grains) in a matrix of fine tridymite, cristobalite and glass. Small amounts of unconverted quartz (about 10 percent) usually remain with nearly equal amounts of lower density forms of silica, cristobalite and tridymite.

Consequently, the fired brick shows a permanent volume expansion of about 13 to 15 percent and a corresponding decrease in density.

3) Glass Sand

Raw materials for the manufacture of glass come primarily from mined minerals and rocks selected for their purity and stable composition, or from those that may be beneficiated to a suitable product.

Precise chemical and physical specifications are usually set for silica sand by glass manufacturers. Silica sand, although it may represent up to three-quarters of a total glass batch mix, is but one of many raw material components, most of which also contain contaminants.

The chemical specifications for silica sand for glass making is dependent on the type of glass for which the sand is being used. A consistent silica sand composition is the most important requirement.

Ideally, the silica sand specification should guarantee a certain minimum purity of material and provide limits on the critical oxides over which the supplier has control. Iron oxide is perhaps the most critical chemical component of all glass making raw materials. Iron control is important because of its effect on glass colour, particularly clear or flint glasses.

The following table lists typical chemical specifications for glass making silica sands.

<u>Material</u>	<u>OXIDE COMPOSITION, %</u>				
	<u>Min. SiO₂%</u>	<u>Max. Al₂O₃%</u>	<u>Max. Fe₂O₃%</u>	<u>Max. Cr₂O₃</u>	<u>Max. CaO+MgO%</u>
White Sand	99	0.10	0.03	0.0003	0.05
Yellow Sand	98.5	0.20	0.25	0.005	0.05

White sand is used for the manufacture of flint or clear glass whereas yellow sand may be used in the manufacture of coloured glass. The major difference between the two sands is the iron and chrome oxide content. Iron and chrome oxides impart shades of green colour to glass; the depth of colour being dependent on the concentration. Flint or clear glass cannot be made if the concentration of these oxides becomes too great.

The physical specifications of silica sand for glass making are also important. Grain size distribution is very critical and normally held between 20 mesh and 100 mesh with a minimum of both coarse and fine material. Coarser fractions should be eliminated to aid melting. The trend is towards minus 40 mesh materials for improved meltability.

Too many fines may cause dust in handling, and problems with refractory erosion in the glass furnace itself. Generally, specifications are set to limit material less than 100 mesh.

4) Enamels

For enamel frits a good grade of fine glass sand is used. Iron content should be less than 0.2 percent; alumina less than 0.5 percent, and silica over 97.5 percent.

5) Pottery Flint

Finely ground silica is used for pottery flint in ceramic bodies. The chief requirements as to purity is that the iron content should be low when a white colour is desired.

6) Sodium Silicate

Sand used in the manufacture of sodium silicate should be very pure. It should contain more than 99 percent silica; with not over 1 percent alumina; not over 0.5 percent lime and magnesia combined; and less than 0.1 percent iron. Grain size is minus 20, plus 100 mesh.

7) Fillers

Finely ground silica is used as a mineral filler in the manufacture of a number of products including:

- paint
- asbestos cement products
- specialty concrete blocks
- bituminous paving compounds.

The primary reason for use of a filler is the reduction of cost of the end product. However, because of the wide variety of natural and processed minerals available for use as fillers, other factors usually determine the final selection.

Physical properties of silica for use in the paint industry, for example, would include: particle size and shape, white colour, and freedom from impurities.

8) Foundry Sands

For foundry sand a highly refractory, tough silica sand having rounded grains with rough surfaces is preferred. The silica sands are bonded with clay and rough grain surfaces improve the bonding power. A sand with a rounded grain is preferred to angular grains owing to the increase in the permeability of the sand, which allows the escape of gases during casting. Grain size is usually between 20 and 270 mesh in closely sized ranges.

Finer grade sands are used for precision castings, and as a base sand for aluminum castings and light copper based alloy castings, as they produce a better finish and finer detail.

9) Silicon Metal

Metallurgical-grade quartz or quartzite is used in the production of silicon metal. Silicon is a relatively low priced commodity whose cost is influenced by availability of cheap energy and convenient transportation. Production capacity is geared primarily to the requirements of the steel and aluminum industries. Annual demand for metallurgical grade quartz is currently over two million tons.

A typical specification of quartzite suitable for silicon production is as follows:

SiO₂ 99.5 percent, Al₂O₃ less than 0.15 percent, Fe₂O₃ less than 0.1 percent, CaO less than 1.0 percent, with a loss on ignition of less than 0.2 percent.

10) Other Uses

Silica is an ingredient in some fibre glass and rock wool products, in cleansing and scouring powders, matches, fertilizer, roofing paper, sandblasting operations, and sandpaper. Various grades of closely sized sand are used in water treatment plants as filtering media. Silica sand is also used in the manufacture of Portland cement which requires 13.6 percent SiO_2 .

High purity quartz is used in the manufacture of silicon wafers and fibres. Northern Telecom, Optical Systems Division, in Saskatoon, Saskatchewan are currently the only fibre manufacturer in Canada. Specifications on the silica purity requirements are considered proprietary information and are not published by the manufacturers. A similar response was encountered when manufacturers of silicon wafers were contacted.

Most consumers have very definite limits of tolerance for impurities. In the ceramic and glass industries, the percentage of iron oxide is important. If the iron content is too high it may be possible to reduce it to the permissible range by beneficiation processes such as acid leaching, air classification or washing.

Moisture in delivered silica sand should not exceed 2.0 percent. A glass sand should all pass 20 mesh with not more than 3 percent passing 80 mesh.

4.2 Glass Sand Beneficiation Processes⁽²⁴⁾

Sand for glassmaking is often included under the general grouping of industrial sands, i.e. those naturally occurring sands or sandstones used for purposes other than construction. The other funda-

mental end-use for industrial sand is foundry moulding. Apart from this, silica - especially when finely ground - is used in many applications, notably ceramics and fillers.

Glass sand is a fine-grained, almost pure quartz material. Grains are usually rounded to a sub-angular rather than angular. A specification will normally demand a minimum of 99.5 percent silica (SiO_2) and a total iron oxide (Fe_2O_3) level of below 0.04 percent. Higher iron levels can be tolerated for the production of green or brown container glass and for flat glass manufacture. In all glass sands the presence of heavy or refractory minerals (heavy minerals being defined by having a specific gravity of 2.9 or more) is deleterious, tending to cause dark specks, irregularities or weak points in the glass. Higher alumina contents are tolerated but alumina content must be consistent and not vary from shipment to shipment.

Gradings normally require that all sand be essentially -35, +150 mesh in size. Large grains require more energy to melt and small grains tend to be lost in the furnace flue. Silica sand accounts for 70 percent of a typical glass melt.

For final comminution of sandstone or quartz to individual sand grains, wet rod and ball mills are used. Once reduced to sand size, almost all silica sand beneficiation processes prior to drying, dry grading or dry grinding require copious quantities of inexpensive, clean neutral water.

4.2.1 Processing Methods

Upgrading sand to a glassmaking material involves a series of processes with up to five main objectives:

- 1) Removal of +35 mesh oversize
- 2) Removal of -150 mesh slimes
- 3) Reduction of Fe_2O_3 content
- 4) Removal of heavy minerals
- 5) Reduction of alumina content

Objectives 1 and 2 always apply; 3 and 4 normally do unless the deposit is exceptionally pure. Objective 5 sometimes applies but is very much dependent of the type of glass to be produced.

4.2.2 Removal of Unwanted Size Ranges

Oversize removal can be carried out on water-jetted vibrating wedgewire screens or occasionally, as by Ottawa Silica, Ottawa, Illinois, by static DSM sieve bends where the amount of oversize is fairly minimal.

Silt removal, on the other hand, is usually effected in quite different ways. In the UK the standard desliming method is the hydrocyclone. Hydrocyclones cutting at about 100 mesh offer a by-no- means perfect wash or perfect separation but do a reasonable job of both and also impart some small measure of scrubbing to the sand, which is useful when iron-rich clays loosely adhere to the grains. Hydrocyclones are inexpensive to install and can be mounted at great height in order to flume off sand into bottom draining bins or into conical naturally draining stockpiles. Their effective operation is governed almost entirely on a fixed mechanical condition, slurry density and, most importantly, the speed of the supplying slurry pump. In recent years a family of machines termed hindered-settling classifiers have become widely used in the UK silica industry. In this case a body of sand is teetered by a rising current of water and the coarser particles

naturally report to the base of the unit. The density of the mass of teetered sand is continuously read by a differential pressure cell which pneumatically triggers a basal valve to open and close, thus releasing the coarser particles and maintaining a constant density in the machine, with therefore a constant grading of the desired product. This type of sand separation is most useful in making clean grading cuts or removing light or fine particles.

American practice is based largely on rake or screw classifiers, both machines pushing a gradually thickening sand pulp up an incline while the wash-water weirs over the back of the machine. Neither of these apparently cumbersome machines gives as good a wash as a hydrocyclone or a hindered-settling classifier and both are prone to losing sand with the wash-water. Another commonly employed American washing method is the elutriator, where a gently rising current of water is introduced into the base of a cone and excess wash-water weirs off the top, a technique mainly applicable to clay removal.

4.2.3 Removal of Unwanted Minerals

The most interesting element of glass sand production is this aspect of its processing. Mineralogical purity is not normally specified for construction sands, though the presence of lignite, peat or shell are examples of impurities which can make a construction sand unacceptable. Foundry sand, while requiring a high (+95 percent) SiO_2 content, is classified by size range rather than chemical purity although alkali and acid demand may be specified for some moulding purposes. In glassmaking the chemical purity of a silica sand is of paramount importance in determining the structural perfection and clarity or colour of the end-product. To understand the relevant processing techniques one must

briefly note how iron-bearing minerals and various non-iron-bearing heavy minerals occur in sands, these modes of occurrence being as:

- clay and agglomerates
- surface iron staining caused by minerals such as limonite, hematite, chamosite and siderite
- a mineral assemblage as above but held in cracks in the grain
- as discrete heavy minerals, both iron-bearing, e.g. ilmenite, magnetite, and non-iron-bearing, e.g. garnet, spinel, kyanite, chromite and tourmaline.
- as mineral inclusions in the grain.

To cope with the removal of these groups of impurities, several treatment processes have been developed. The main approaches are listed below, with notes on the type of contaminant which is removed.

- 1) Washing - clays, some agglomerates
- 2) Attrition scrubbing - agglomerates, surface staining
- 3) Froth flotation - iron-bearing and heavy minerals, feldspar
- 4) Dilute acid leaching - strongly adhered surface staining
- 5) Hot acid leaching - effective removal of surface and sub-surface staining.

- 6) Dry or wet magnetic separation - removal of magnetic minerals from glassmaking sands.

4.2.4 Washing Process

These are generally synonymous with silt removal and as such have been discussed. The washing process also serves to pulp the feed prior to attrition, flotation and cold acid leaching.

4.2.5 Attrition Scrubbing

This involves the high-speed agitation of a high-density (75-80 percent solids by weight) pulp to create conditions of maximum particle-to-particle contact in order to break down clays and agglomerates. The process is enhanced if the pulp is made acid or alkali. Several stages of attrition with intermediate washes may be required in a dirty feed. This practice is far more widespread in the U.S.A. and Canada where it is regarded as necessary in order to clean the sand prior to froth flotation, or as a clay removal process prior to desliming. The variable cost, assuming a neutral scrub, is largely in the high power input required, normally about 3.75 kW/tonne. Scrubbing is particularly applicable if a deposit is clay-bearing; in this case the process not only ultimately lowers iron levels but also combats an over-high alumina content by breaking up and dispersing clays for subsequent washing off. Most American plants have a sophisticated system for maintaining a high slurry density (without which the process is useless) by varying the make-up water input according to the amperage read on the first cell.

4.2.6 Flotation

The conditioned pulp passes into a flotation machine. Commonly used collectors are petroleum sulphonate (in an acid pulp), fatty acids and tall oils (in neutral or alkali floats).

All major producers of flint glass sand in the UK employ some degree of flotation. The commonly used float on Lower Greensand deposits and on the Millstone Grit in Staffordshire employs petroleum sulphonate collector in an acid ($\text{pH} \leq 3$) environment.

American flotation practice varies widely accordingly to the level and type of contaminant in the feed and the particular product specification aimed at. A petroleum sulphonate float is used at the Carolina Silica Co. plant at Marston, North Carolina, in this case following two separate stages of attrition scrubbing. At Pennsylvania Glass Sand, Millville, New Jersey, an alkaline float has been found best for removing the troublesome refractory minerals kyanite and sillimanite. In California both Martin Marrietta, at Byron, and Ottawa Silica, at Oceanside, use neutral floats. California State regulations governing water pollution are so stringent that acid flotation is practically precluded. A combination of tall oils, fatty acids and some petroleum sulpho-nate are used but the result is a less selective float. In this case, achieving sufficient output to satisfy demand is currently overriding the need to produce a product sand of good chemical purity. The nearest source of high-grade silica to California is 1,500 miles away in Missouri. In some cases this is shipped in and blended with local sands.

For the glass sand industry, froth flotation is the universally used process for the removal of iron-bearing and heavy minerals.

If the plant is of sufficient capacity and the cost of the necessary reagents can be absorbed, then up to 90 percent of discrete minerals can be removed. Alternatively, the process can be used to remove the worst of the contaminants to produce an acceptable end-product for further treatment.

4.2.7 Dilute Cold Acid Leaching

This process is applicable to the removal of stubborn surface iron staining. It involves slurring the feed at high density in a turgid pulp made acid by sulphuric, or more effectively but expensively, by hydrofluoric acid. Solid sodium hydrosulphite is added and the solution partially dissolves iron from the surface of the grain.

4.2.8 Hot Acid Leaching

This process represents the, as yet, ultimate practical method of reducing Fe_2O_3 levels present as staining or in cracks in the grain. The cost of the process is about double any combination of those previously discussed. The feed sand must first be dried before the addition of a specific quantity of sulphuric acid and a minimal amount of moisture. The whole mix is then slowly tumbled for 40-50 min in a refractory-lined drum before a thorough multi-stage final wash.

One such plant is operated by Central Silica of Ohio, a small company that supplies very local glass and ceramic markets. The company is located between the major Oriskany and St. Peter sandstone producers and can thus tolerate the high process costs because of lower freight charges.

Hot acid leaching is employed in the UK to reduce Fe_2O_3 levels on heavily stained Millstone Grit. The inescapable high variable

costs can be reduced slightly by using spent acid from another major industrial user's process.

4.3 Production and Consumption

The following table⁽³¹⁾ illustrates Canadian production, use and import sources of silica in 1981 and 1982.

Table 1. Canada Silica Production and Trade, 1981 & 1982

	1981		1982	
	<u>1000's tonnes</u>	<u>1000's \$</u>	<u>1000's tonnes</u>	<u>1000's \$</u>
Production, quartz and silica sand				
Quebec	695	12,950	705	13,781
Ontario	901	10,969	482	8,292
Alberta	..	3,173	..	3,088
Manitoba	198	2,284	164	2,688
Nova Scotia	..	2,334	..	1,401
New Brunswick	..	1,000	..	1,400
Saskatchewan	142	1,169	97	1,049
Newfoundland	..	768	..	1,632
British Columbia	..	46	..	36
TOTAL	<u>2,238</u>	<u>34,693</u>	<u>1,797</u>	<u>33,367</u>
By Use:				
Glass & Fibreglass	489	12,542	..	..
Flux	837	4,054	..	..
Ferrosilicon	339	3,193	..	..
Other uses	573	14,904	..	..
TOTAL	<u>2,238</u>	<u>34,693</u>	<u>1,797</u>	<u>33,367</u>
Imports, Silica Sand				
United States	1,142.8	18,467	788.5	15,475
United Kingdom	.1	3	-	-
Other Countries	-	-	0.3	120
TOTAL	<u>1,142.9</u>	<u>18,470</u>	<u>788.8</u>	<u>15,595</u>

.. Data not available.

Nova Scotia's 1982 silica production is discussed as follows:⁽³¹⁾ "Nova Scotia Sand and Gravel Limited processed silica sand suitable for sand-blasting, glass, fibreglass and filter sands from their plant in Shubenacadie. Most of the product was marketed in the four Atlantic provinces. Crushing facilities for beneficiation of sand for flint glass were completed in 1982. Sales in 1982 were down by a large margin and at least one former customer went bankrupt due to the recession."

However, a more recent picture of the U.S. situation is more optimistic⁽³²⁾. Production and consumption of industrial silica in 1984 improved beyond most companies expectations. Sales of this mineral expanded rapidly in the first half of the year.

Preliminary estimates are that 26 million tonnes were sold or used at a value of \$370 million. This is an increase of nearly 11.2 percent in production and 12.3 percent in value.

Production in 1984 was the highest since 1981. The value of the products sold increased 12 percent. This rather small change is most likely a direct result of excess productive capacity controlling prices.

4.4

Markets, Prices

The markets, consumption and related matters are not within the scope of this study and only general remarks and comments on this subject are included here.

The established steel industry is a consumer of large amounts of silica flux, moulding sand, refractory silica bricks and blasting sand. Although glass, fibreglass and ceramic industries exist in the Atlantic Provinces they only represent a relatively minor production capacity at this time.

A recent review⁽³²⁾ of the glass markets (generally) emphasizes the general improvement with the exception of glass containers. Aging plants and equipment, excess capacity and competitive products contributed to the decline of the glass container market. However, glass containers still represent the largest market for industrial silica, about 26 percent.

Glass containers manufacturing is expected to decline about 1 percent per year over the next three years. Plastic containers are expected to grow at a rate of 5 percent per year.

Flat glass production improved in 1984 with 90 percent of U.S. plant capacity operating throughout the year. Some major expansions were taking place in the United States as well as in Canada, where LOF Glass of Canada Ltd. is expanding its plant in Collingwood, Ontario, at a cost of about \$44 million.

This expansion was necessary due to the increase in automobile production, construction industry and housing starts. Economic recovery was also noted in the foundry industry with the number of castings up 23.8 percent.

Price declines were registered in nearly all sections of U.S. silica sand industries, reflecting the major market forces of demand and supply. Industrial sand prices are expected to lag the producer price index change. The average value of sand shipments in 1984 was estimated at US\$14/t, a 0.9 percent improvement over 1983.

5.0

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①

PETROLOGY OF LOWER CRETACEOUS SILICA SANDS
AT BRAZIL LAKE, HANTS COUNTY, NOVA SCOTIA

R. R. Stea and J. H. Fowler

INTRODUCTION

A large deposit of silica sand near Brazil Lake, Nova Scotia, has recently been developed by Nova Scotia Sand and Gravel Limited. This discovery extends the range of known occurrences of Lower Cretaceous sediments to a large part of the Shubenacadie and Musquodoboit structural basins (Fig. 1). Silica sands and lignite are also known to occur underneath Pleistocene sands and gravels of an esker-outwash system 4 km due south of the Brazil Lake occurrence (H. Cross, pers. comm.). Lignite from this locality contains a floral assemblage similar to that reported by Stevenson and McGregor (1963) indicating a Lower Cretaceous age (M.S. Baras, pers. comm.). Carbonaceous grey clay at the Brazil Lake site, however, produced only Windsor Group palynomorphs, but these are believed to have been reworked from the underlying Windsor Group bedrock.

This project has been initiated to evaluate sedimentology, stratigraphy, and economic potential of the Cretaceous deposits in Nova Scotia one by one. In this way a better understanding of these enigmatic sediments can be gained as the information from each site is obtained and synthesized. Although the mineralogy and economic potential of these deposits have been outlined (e.g. Ries and Keele, 1911; Fowler, 1972) the details of petrology have just been barely touched upon (Benteau, 1973).

STRATIGRAPHY

The Brazil Lake pit (Fig. 2) revealed a striking sequence of brightly coloured sediments in unconformable contact with overlying Pleistocene glacial deposits. The Cretaceous beds were found to strike at 25° with a 35° dip to the north that seemed to be consistent along strike throughout the pit. Some beds also appeared to be vertical. The unconformable nature of the Pleistocene-Cretaceous contact is well illustrated in a cross-section through subsurface deposits of silica sand at Elmsvale (Fig. 3, Fowler, 1972).

One part of the pit displayed a section showing two distinct fining upward cycles spanning 4 m (Fig. 4). At the base of the sequence was exposed a whitish sandy cobble gravel (unit 1) grading into a sandy mud (unit 6). Following this cycle was a sandy gravel (unit 7) grading into a well sorted sand (unit 9). These units were capped by another coarse unit (10) (sandy pebble gravel). The mud unit, pink in colour, displayed numerous black and white micaceous silt laminae. Some of the laminae were highly contorted. Black and red staining were visible in the sand units. Swirls of reddish-brown staining (iron-oxide?) were found to crosscut bedding near the top of the sequence (Fig. 4).

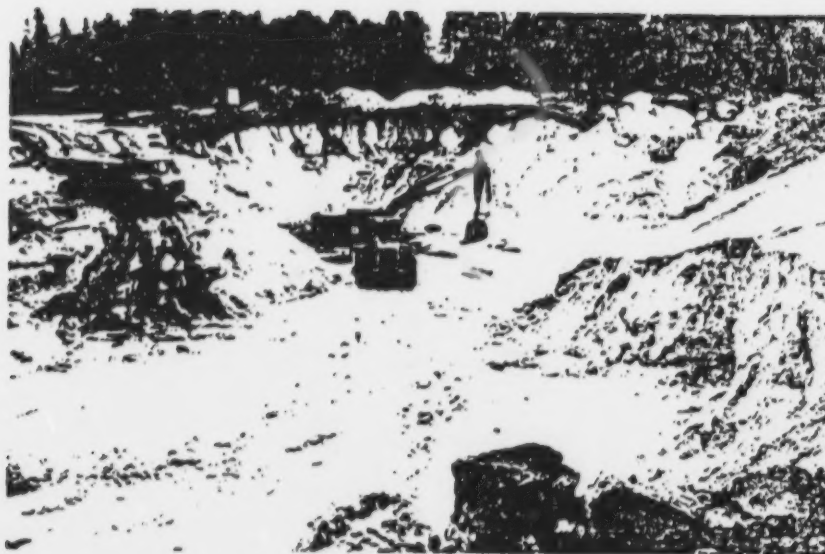


Figure 2. A view of the silica-sand quarry near Brazil Lake, Hants County, Nova Scotia.

PETROGRAPHY

Methods

Eleven samples were obtained from the pit face covering every sedimentary unit exposed. Grain size analyses were done on the samples using standard sieving and pipetting techniques. Modal size fractions of the sediments were mounted in epoxy in a section of glass tubing and then thin sectioned. Heavy minerals were separated from the 1.5 to 4.5 phi size fractions for all samples except 6 and 7 which used the 6 phi fraction. Tetrabromethane (s.g. = 2.95) was used in the separation. Representative cobbles in the lowest coarse unit (1) were thin sectioned. Two slides were made from splits of the heavy minerals and modal fractions. Two hundred and fifty grains were counted (employing the ribbon method) to determine the per cent opaque minerals and at least another 100 translucent grains to determine percentages of the translucent minerals. Mineral species were identified using the petrographic microscope and later verified qualitatively using the electron microprobe apparatus at Dalhousie University. A composite sample of the heavy minerals was also analyzed semiquantitatively for 32 elements by Emission Spectroscopy by Bondar-Clegg & Co. Ltd.

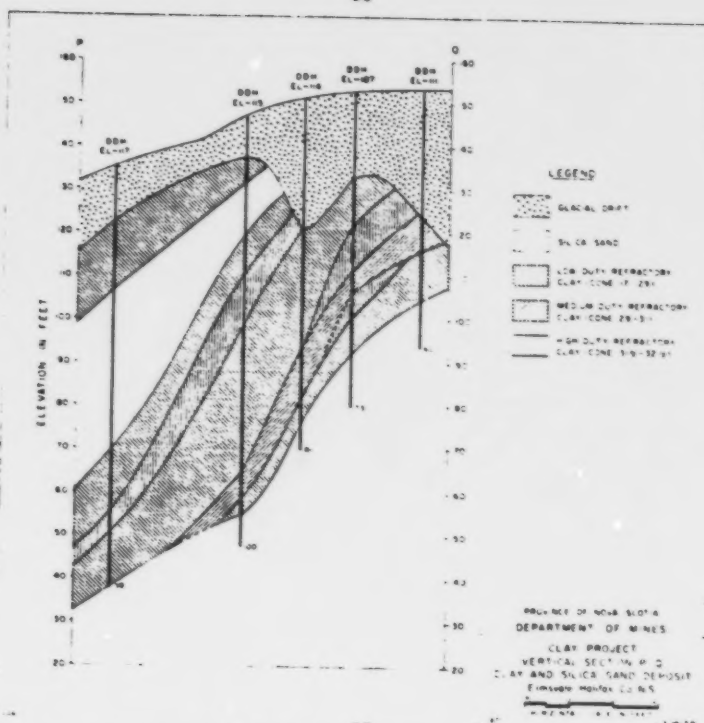


Figure 3. A cross-section through Cretaceous deposits at Elmsvale, Nova Scotia (after Fowler, 1972).

Petrographic Summary

Quartz is the most abundant mineral in the modal fractions accounting for greater than 98% of all minerals observed. The grains are predominantly angular; the sediments in general exhibit poor roundness sorting. The quartz grains consist primarily of strongly undulose single and composite types. Kaolinitic clay and mica become major constituents in units 5 and 6 (Fig. 4). Feldspar is a minor constituent comprising less than 1% of the modal fractions. Gypsum was found to occur in abundance in samples 6-9 as brown, rod shaped, brittle grains concentrated in the finer fractions.

Heavy minerals comprise from 0.3 to 2.9% of the fine- and medium-sized sand fractions of the samples. Of these, opaque minerals are predominant averaging 92% of all the heavy minerals. Ilmenite is the most abundant opaque. Hematite is also present in substantial amounts. The heavy mineral grains are mostly rounded. Of the translucent

grains, yellow angular staurolite is the most abundant (36%) followed by rounded fractured zircon (31%), angular and rounded tourmaline varieties (12%), a rare earth phosphate (11%) and barite (3%). Andalusite (2%), cassiterite, garnet and amphibole-feldspar rock fragments ? are minor constituents (<2%).

Texture

As seen in Figure 4 the samples range from poorly sorted to moderately well sorted. The sediments contain clay sizes to cobbles >20 mm in diameter. Sample 1 displays two modes, one in the cobble-pebble range and another in the coarse sand range. The lower five samples in the first cycle define a fining upward trend. Modes in these samples become displaced up section to the medium and fine sand ranges. Samples 1-5 also show a negative skewness.

Samples 6 and 7 are sandy muds with strong bimodality. The upper three samples of the second cycle define a fining upward trend truncated with a well sorted sand (unit 9). These samples however, show positive skewness unlike the lower samples.

Modes of roundness classes of Powers (1953) range from very angular to subangular while the sediments generally display poor roundness sorting (Fig. 4). The most frequently occurring roundness class is angular. The quartz in the coarser modal fractions (samples 1 and 11) displays greater angularity than the quartz in the finer ones (sample 6). Some individual grains show the round and angular edges (Fig. 5b).

Mineralogy

Quartz is extremely abundant in the modal fractions comprising greater than 98% of the total minerals. Most of the quartz grains examined in the modal fractions fell into classes 3 or 6 of Folk's (1974) empirical classification scheme. These are single and composite grains with strongly undulose extinction. Many of the composite grains also have granulated sutured boundaries with stretched individual grains (Fig. 5b). The tendency throughout the section was an increase in type 6 grains in the coarser grade sizes which may be a reflection of the incomplete breakdown of these polycrystalline quartz grains.

Feldspar is virtually absent in the sands studied. One fresh looking twinned plagioclase grain was noted in the examination of the modal fractions. The thin sections of the modal fractions were all stained with sodium cobaltinitrate and showed no evidence of potassium feldspar. The dearth of feldspar is further evidenced by bulk analyses of sands from the site (Table 1).

Units 7, 8 and 9 show an abundance of rod shaped brown gypsum grains especially in the finer fractions. They seem to have accompanied the abundant interstitial clay in these samples.

Units 5 and 6 contain a high percentage of muscovite mica as tiny flakes with the quartz and clay.

(1) **business classes after Powers (1953)**

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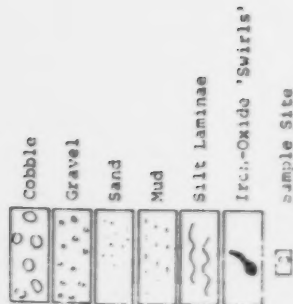
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Figure 4

LEGEND



[2] Sample Site

This figure depicts two fining upward cycles of Lower Cretaceous sediments exposed at Brazil Lake and some relevant secondary parameters. The grain size distribution for each cycle is shown on the far left. The asterisks above the distribution refer to the modal fractions mounted for microscopic examination. The heavy minerals were extracted from the 0.075 mm size intervals for each sample except 6 and 7 where the 0.4 mm fraction was utilized.

(a) roundness classes after Powers (1953)

- 1 very angular
- 2 angular
- 3 subangular
- 4 subrounded
- 5 rounded
- 6 well rounded

(b) quartz extinction types after Polk (1974)

- Single Grains 1 straight extinction
- 2 slightly undulose extinction
- 3 strongly undulose extinction
- Composite Grains 4 straight undulose extinction
- 5 slightly undulose extinction
- strongly undulose extinction

(c) the percentage instable minerals refers to the percentage of garnet + andalusite in the translucent heavy minerals. These minerals are believed to be relatively susceptible to chemical attack.

Table 1. Chemical analyses of a bulk sand sample from the Brazil Lake sandpit (analyses provided by Nova Scotia Sand and Gravel Ltd.).

CHEMICAL ANALYSIS	PER CENT
Silica (SiO_2)	99.1
Alumina (Al_2O_3)	0.38
Iron Oxide (Fe_2O_3)	0.14
Calcium (CaO)	0.00
Magnesia (MgO)	0.00
Sodium (Na_2O)	0.00
Potassium (K_2O)	0.02
L.O.I. @ 1200°C	0.32
Total	100.0

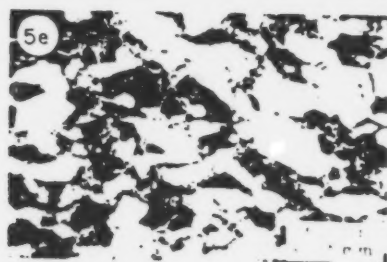
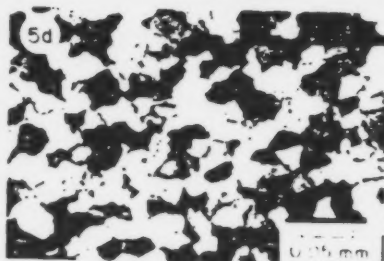
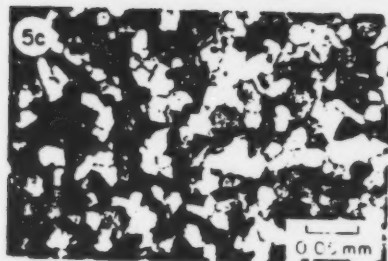
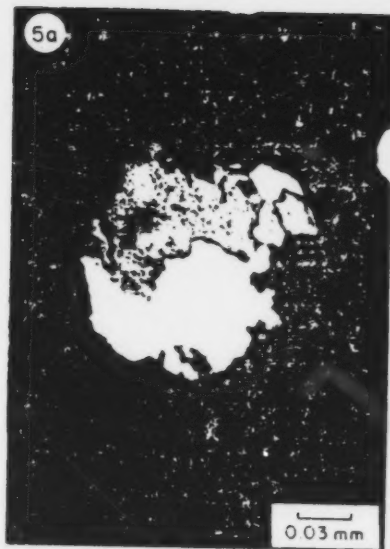
The clay at this locality was not mineralogically analyzed, but is visibly similar to the clays reported at Shubenacadie (Stevenson and McGregor, 1963), Elmsvale (Fowler, 1972) and Musquodoboit (Lin, 1971). A sample of clay from Paint Brook in the Musquodoboit Valley was found to consist primarily of quartz, disordered kaolinite and dioctahedral mica of variable crystallinity (Dean, 1970). Hematite, anatase and rutile were found to be minor constituents. Dean (1970) stated that some of the micas displayed features of intense weathering, a near absence of layer stacking order and the replacement of K^+ ions by smaller cations.

HEAVY MINERALS

The heavy minerals are dominated by opaques (92%). Ilmenite, as predominantly rounded detrital grains, is the most common opaque mineral. Ilmenite completely altered to leucoxene is generally scarce (<2%). Hematite is next in abundance as detrital and authigenic ? grains and is also believed to be present as inclusions in the ilmenite. Some sulphides also may be present in trace amounts. The quantitative importance of titanium and iron in the heavy minerals is evidenced by the high analytical values of these two elements (Table 2).

Figure 5a. Individual quartz grain showing composite nature and sutured boundaries (crossed nichols).

- 5b. Very angular and angular quartz grains, some having rounded edges. Assemblage typical of the sands (crossed nichols).
- 5c. Quartz arenite cobble #1 (coarse beds, cycle 1, Fig. 4), relatively undeformed (crossed nichols).
- 5d. Quartz arenite cobble #2, slightly deformed (crossed nichols).
- 5e. Quartz arenite cobble #3, intensely deformed (crossed nichols).



Yellow, pleochroic angular staurolite is the most abundant translucent mineral (Fig. 6a). It is present as 36% of the translucent minerals. The grains show abundant quartz inclusions and appear to have etched edges. Staurolite appears to be concentrated in coarser grade sizes (Fig. 4).

Zircon is next in abundance (31%) (Fig. 6c). The grains are predominantly rounded with some subhedral forms. One euhedral grain was noted. Much of the zircon displays a fracture pattern. The zircon is most abundant in the finer grade sizes and tends to be most abundant in samples with a fine tail or mode in the 2-4 phi range. The antithetic relationships with staurolite are well illustrated in Figure 4.

Tourmaline (12%) is present in the following five varieties in order of abundance: yellow-orange angular grains (Fig. 6c), green angular grains, green rounded grains with abraded and etched overgrowths (Fig. 6d), yellow-orange rounded grains, and idiomorphic blue grains.

A rare earth phosphate is present in large quantities (11%) as rounded, subtranslucent grains (Fig. 6b). Table 2 shows a high percentage of rare earth elements corresponding to this mineral phase.

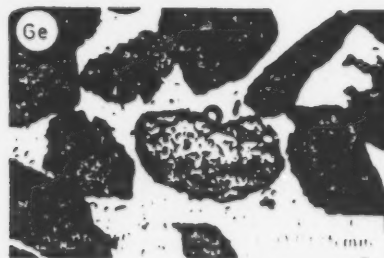
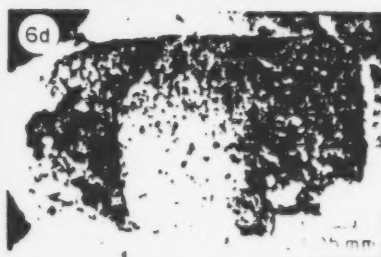
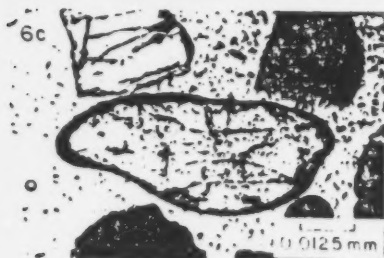
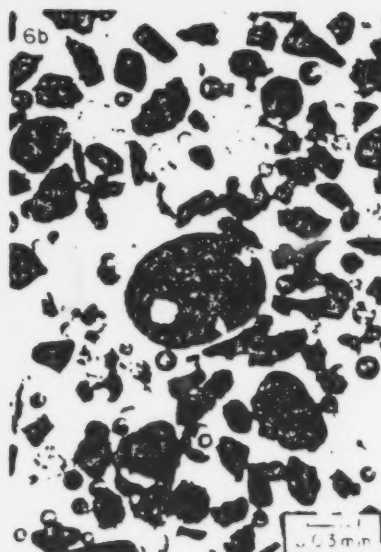
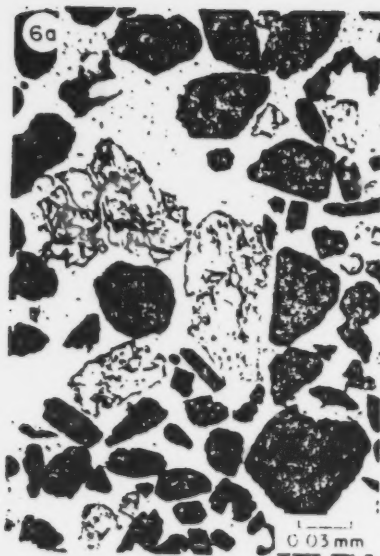
Andalusite is present in minor amounts (2%) as angular, clear and red grains with one direction of prominent cleavage. Some fresh and altered isotropic garnet grains were found. Angular barite grains are also present in minor amounts. Cassiterite grains were also noted (Fig. 6e). Fragments consisting of amphibole and feldspar were also discovered in samples 2 and 3.

SECTIONED COBBLES

All the cobbles that were thin sectioned were quartz arenites (Fig. 5c,d,e) moderately sorted showing various stages of cataclastic deformation. One cobble is intensely deformed displaying smeared out quartz grains and sutured, granulated grain boundaries (Fig. 5c). Another cobble is less intensely deformed exhibiting some evidence of stretching and traces of recrystallization (Fig. 5d). Most individual grains in this cobble demonstrate strongly undulose extinction. The third rock sectioned is an undeformed quartz arenite cemented by silica,

Figure 6. Heavy minerals.

- 6a. Staurolite grains (translucent with etched boundaries) among opaque rounded and angular grains (mostly ilmenite).
- 6b. Large, rounded semitranslucent grain of a rare earth phosphate (in centre of photograph).
- 6c. Rounded, fractured zircon grain (high relief) flanked by two intensely green pleochroic tourmaline grains.
- 6d. Tourmaline grain, rounded, with an abraded and etched authigenic overgrowth.
- 6e. Cassiterite grain (translucent).



MAJOR ELEMENTS (%)	<.003	.003-.01	.01-.03	.03-0.1	0.1-0.3	0.3-1.0	1.0-3.0	3.0-10.0	> 10.0
SiO ₂									X
Al ₂ O ₃									X
Total Fe (Fe ₂ O ₃)									X
MgO						X			X
CaO					X				
Na ₂ O						1	X		
K ₂ O				X					
TiO ₂								(X)	
TRACE ELEMENTS (%)									
V					X				
Cr	X								
Mn									
Co	X					X			
Ni	X								
Cu		X							
Zn	X								
As	X								
Sr		X							
Y		X							
Zr						(X)			
Nb		X							
Mo	X								
Ag	X								
Sn				(X)					
Sb	X								
Ba						(X)			
La				(X)					
Ce				(X)					
W	X								
Pb	X								
Bi	X								
Tl	X								
U	X								

with subangular to subrounded and
found in abundance. A few of
the tourmaline pebbles are
pebbles of high quality.

It is apparent that the local source of the fine grained some samples. The organic clay is not red.

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with subangular and subrounded grains. Rounded tourmaline grains are found in abundance. A few rounded zircons are also present. Some of the tourmaline shows spikes of authigenic overgrowths. Vein quartz? pebbles of high sphericity and roundness were also found to be common.

INTERPRETATION

Provenance

It is apparent that the underlying Windsor Group provided a local source of detritus for the sands. Gypsum grains are evident in some samples. Lower Windsor Group palynomorphs were noted in a grey organic clay unit exposed in the pit.

The Cheverie Formation (Horton Group) exposed a few kilometres to the north of the Brazil Lake site (Stevenson, 1959) also may have provided an important source of sediment. Grey-white quartz arenite cobbles found in the coarse lag beds closely resemble the basal or the quartzite member of the Cheverie Formation described by Freeman (1972). The quartz varieties present in the sands are also suggestive of a sedimentary source, but one that has been subject to deformation. Since faulting is common in the Carboniferous sediments of the area the presence of sheared quartz grains and cobbles can be explained. Numerous second cycle zircon, tourmaline and barite grains suggest a sedimentary source. Zircon and tourmaline have been described in the Horton Group sediments (Freeman, 1972; Macdonald, 1973). The fractured zircon grains noted in the Cretaceous sediments are very similar to those described by Worth (1969) in the Horton Bluff Formation (Horton Group). Ilmenite, found in great abundance, may also have been derived from the Carboniferous or Triassic rocks (including basalt) to the north. The occasional amphibole-feldspar fragment present suggests a Cobequid Highland acid igneous source area because amphibole is a common constituent of the intrusive rocks of the Cobequid Highlands (Weeks, 1948) and not generally known to be present in the intrusive rocks of the South Mountain batholith (McKenzie and Clarke, 1975).

The presence of abundant staurolite in the sediments is enigmatic. The main source areas for staurolite in the Province are in the amphibolite facies metamorphic rocks of the Meguma Group in the Shelburne and Canso areas. These areas, however, are quite far removed from central Nova Scotia and a paleoriver connection with either area to the Brazil Lake site seems tenuous. The staurolite may be recycled from Carboniferous and/or Triassic sediments to the north or be derived from Cobequid Highland metamorphic rocks which may contain some staurolite. Clifton (1963), discovered staurolite in Triassic and Carboniferous sandstones as well as the Pembroke Breccia which outcrops along a wide belt paralleling the Minas Basin shore. Nielsen (1976) noted that a distinctive dispersal fan of staurolite in the Walton area emanates from a source in the Minas Basin to the north. Benteau (1973) also noted the presence of staurolite in Cretaceous sands at Shubenacadie.

Depositional Processes

This section of Lower Cretaceous sediments exhibits a fining upward sequence with sandy gravel at the base to mud at the top. This sequence is a characteristic of point bar deposits of meandering streams (Pettijohn, 1975). Benteau (1973) noted the presence of lignite fragments and intraformational grey clay in the coarse basal beds, also a characteristic of fluvial systems. The depositional cycles represented in the section (Fig. 4) then begin with a traction load deposit at the base of a channel progressively overlapped with finer sediments as the stream migrates laterally. The contact of cycles 1 and 2 (Fig. 4) is probably due to the initiation of a new succession of deposits through the lateral migration of another meandering stream. The lack of primary bedding features in the sands, although noted at Shubenacadie by Benteau (1973), may be due to the tectonism that had tilted the sequence, or may be an apparent feature due to the absence of lithification.

Post-Depositional Processes and the Cretaceous Problem

The lack of feldspar and phyllic rock fragments in these sediments, interpreted to be fluvial, is a paradox. Most modern fluvial sands are lithic and/or feldspathic, the average in large rivers being 19 and 15 per cent respectively (Pettijohn, et al., 1972). This lack of feldspar has been noted in terrestrial Cretaceous sands all over the continent (Hamblin, 1979; Pirkle, et al., 1964; Pryor, 1960) and in the marine sandstones of Lower Cretaceous age offshore (King, et al., 1969). Several factors that may produce a quartz rich sediment are: a quartz rich source area; physical abrasion during transport; chemical weathering in the source area; postdepositional subaerial weathering; and postdepositional intrastratal solution.

The presence of abundant mica in the finer sediments at Brazil Lake occurrence and heavy minerals of a sedimentary granitic association suggests that there probably were sources of feldspar in the catchment area. Large batholiths virtually surround the occurrence. In addition, the lack of feldspar in these sediments seems to be a characteristic of Cretaceous sediments in general and not just a local phenomenon. One can therefore assume that the mineralogy of the source area was only a minor factor in controlling the petrology of these sediments.

The angularity of the quartz grains (Fig. 5b) and the inferred fluvial environment of deposition precludes physical abrasion as an important process in the depletion of feldspar in these sediments.

The association of high grade kaolinite in these silica sands indicates that chemical weathering of the feldspars has occurred. Kesler (1963) attributed the origin of the silica-sand-kaolin deposits in Georgia to weathering in situ of feldspathic sands and subsequent redistribution in a deltaic environment to separate the clay and sand. Nova Scotian deposits, however, are of terrestrial, fluvial origin (Lin, 1971; Benteau, 1973). Pirkle, et al. (1964) also postulated a fluvial origin for the Cretaceous Citronelle Formation in Florida. They found abundant field evidence for this, citing the occurrence of armored kaolin balls, for example (Pirkle, et al., 1964). They maintained

that the clays were primary sedimentary deposits and not postdepositional products of weathering or intrastratal solution. They also suggested that the clays were originally kaolinite and not some other mixture of less stable clays that were diagenetically transformed. The lack of weathering of other components in the sediments, primarily ilmenite, lent some weight to their hypothesis. The clays at Brazil Lake are segregated according to primary depositional features as part of a fluvial fining upward sequence. The lower beds are noticeably deficient in clays (Fig. 4). If the clay beds were formed by a process of intrastratal solution of a feldspathic sand it would be difficult to explain the relatively clay free silica sand beds.

Hester (1974) suggested that postdepositional subaerial weathering was an important process in the depletion of feldspar and garnet in the Cretaceous Cussetta sand of Georgia. In the Nova Scotian deposits, one cannot judge the effects of this process readily because much material may have been stripped off during the multiple glaciations of the region.

Samples 6 and 7 (Fig. 4) are from relatively impermeable beds. If postdepositional processes were operative and a major controlling factor in the mineralogy of the heavy minerals, for example, one would expect a greater number of chemically unstable heavy minerals (e.g. garnet, amphibole) in these impermeable beds (Blatt and Sutherland, 1969). The abundance of garnet, amphibole and andalusite however, actually decreases in these beds, and no new unstable varieties were noted. Pirkle, et al. (1974) also found a lack of garnets in impermeable kaolinite lenses associated with the Citronelle Formation silica sands. One can rule out hydraulic factors because large grains of staurolite were also found in the mud unit (unit 6), in addition to zircon. The presence of relatively fresh plagioclase and garnet grains in the porous sand units, and the increase in the unstable heavy minerals upsection (Fig. 4) weigh against both subaerial weathering and intrastratal solution.

Dryden and Dryden (1946) noted that Lower Cretaceous sands in Maryland, derived presumably from a nearby garnetiferous schist unit, contained little or no garnet while older and younger rocks of similar permeabilities contained abundant garnets. They attributed this depletion to source area weathering. Clifton (1963), working in central Nova Scotia, found euhedral garnets to be common in porous Triassic sandstones of the Wolfville Formation, in Carboniferous sandstones, and in Pleistocene and recent sands, but found none in the Cretaceous sands he studied.

The suite of heavy minerals found in the Nova Scotian deposits differs from many published assemblages of fluvial Cretaceous sands, in the abundance of ilmenite and staurolite. It is a 'limited' assemblage in the sense of Groot and Glass (1960), characterized by a lack of chemically unstable heavy minerals such as garnet and epidote. One exception to this rule however, seems to be the Cretaceous silica sands of the Hudsons Bay Lowlands where hornblende and garnet are major constituents (Hamblin, 1979). If source area weathering is a major controlling influence on the mineralogy of these silica sands then it may have been variations of climate that produced the contrasting heavy mineral suites.

ECONOMIC CONSIDERATIONS

Nova Scotia Sand and Gravel undertook development of this deposit with production commencing in 1978. Annual production includes 50,000 tons industrial sand, 11,000 tons shipped for glass manufacturing and 9,000 tons for the manufacture of fibre glass insulation. Assays of pit run sand samples run as high as 99% SiO_2 (information from N.S. Sand and Gravel).

A composite heavy mineral sample from eleven sand samples collected from the Brazil Lake deposit gave the following results: gold 240 ppb, tin 737 ppm and titanium ranging from 3 to 10% (assays by Bondar-Clegg & Company Ltd. for Nova Scotia Department of Mines and Energy). In 1972 Glooscap Minerals reported 40% Ti from concentrations of sand in the delta and tidal section of the Shubenacadie River.

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2

NOVA SCOTIA SAND AND GRAVEL
SILICA SAND
NO: 1/8" Minus

PRODUCT DATA

SILICA SAND IS FULLY WASHED AND DRIED. IT IS ANGULAR & SUB-ANGULAR IN SHAPE AND EXTREMELY PURE SILICA.

TYPICAL CHEMICAL ANALYSIS

SiO ₂	98.7
Fe ₂ O ₃	0.20
Al ₂ O ₃	0.18
TiO ₂	0.52
CaO	< 0.05
MgO	0.01
L.O.I. @1200°C	0.13

TYPICAL SIEVE ANALYSIS

<u>CAN. STD. SIEVE</u>	<u>RETAINED</u>	<u>PASSING</u>
20	4.0	96.0
30	7.1	88.9
40	10.6	78.3
50	22.5	55.8
70	22.6	33.2
100	24.9	8.3
140	6.8	1.5
200	1.2	.3
Minus 200	.3	

PHYSICAL PROPERTIES

MOH Hardness	7
Specific Gravity	2.6

NOVA SCOTIA SAND AND GRAVEL
SILICA SAND
NO. "2"

B

TYPICAL SIEVE ANALYSIS

<u>CAN. STD. SIEVE</u>	<u>RETAINED</u>	<u>PASSING</u>
8	-	100
12	27.6	72.4
16	59.4	13.0
30	12.8	.2
40	.1	.1
100	.1	
Minus 100	-	

PHYSICAL PROPERTIES

High Silica Content

Particles are Angular and Subangular

Effective Size .84mm

Uniformity Coefficient 2.00

Specific Gravity 2.6

MOH Hardness 7

Weight Per Cubic Foot 100 lbs. (Loose)

NOVA SCOTIA SAND AND GRAVEL
SILICA SAND
NO. "1"

TYPICAL CHEMICAL ANALYSIS

SiO ₂	98.7
Fe ₂ O ₃	0.20
Al ₂ O ₃	0.18
TiO ₂	0.52
CaO	0.05
MgO	0.01

TYPICAL SIEVE ANALYSIS

<u>CAN. STD. SIEVE</u>	<u>RETAINED</u>	<u>PASSING</u>
4	-	-
12	-	100
16	7.1	92.9
20	42.6	50.3
30	42.9	7.4
35	5.8	1.6
40	1.0	.6
100	.6	
Minus 100	-	

PHYSICAL PROPERTIES

High Silica Content	
Particles are Angular and Subangular	
Effective Size	.60mm
Uniformity Coefficient	1.70
AFS No.	16
Specific Gravity	2.60
HOH Hardness	7
Weight Per Cubic Foot	100 lbs. (Loose)

1)

NOVA SCOTIA SAND AND GRAVEL
SILICA SAND
NO. "0"

TYPICAL SIEVE ANALYSIS

<u>CAN. STD. SIEVE</u>	<u>RETAINED</u>	<u>PASSING</u>
16	-	100
20	.7	99.3
30	36.7	62.6
35	33.4	29.2
40	18.8	10.4
70	9.1	1.3
100	1.2	.1

PHYSICAL PROPERTIES

High Silica Content
Particles are Angular & Subangular
Effective Size .42mm
Uniformity Coefficient 1.40
AFS No. 28
Specific Gravity 2.60
MOH Hardness 7
Weight Per Cubic Foot 100 lbs. (Loose)

E

NOVA SCOTIA SAND AND GRAVEL
SILICA SAND
NO. "00"

TYPICAL SIEVE ANALYSIS

<u>CAN. STD. SIEVE</u>	<u>RETAINED</u>	<u>PASSING</u>
20	-	100
30	1.1	98.9
40	18.5	80.4
50	36.4	44.0
70	29.0	15.0
100	13.5	1.5
140	1.4	.1
Minus 140	.1	

PHYSICAL PROPERTIES

High Silica Content
Particles are Angular & Subangular
Effective Size .18mm
Uniformity Coefficient 2.00
AFS No. 46
Specific Gravity 2.60
MOH Hardness 7
Weight Per Cubic Foot 100 lbs. (Loose)

4

430177

44-D-0201



PRELIMINARY

REPORT
ON

WHITE SANDS

NEAR

BEAUFORT

COLCHESTER COUNTY

L.S.

BY

A. E. Cameron

Halifax, N.S.
March 20th
1961

Cameron & Cameron
Consulting Engineers

f

WHITE SANDS

NEAR

BELMONT

N.S.

Location

The properties upon which the 'White' Sand deposit is located are located north of the village of Grove's Mills, Colchester County about 9 miles west of Truro and 4 miles north of Hc. 2 Highway. A black topped paved secondary road passes through Belmont, 1 1/8 miles west of the deposits. Belmont is a station on the main line of the Canadian National Railways with sidings for freight loadings and unloadings.

The white sands are exposed in two separate pits about 1/4 mile apart and differing in elevation by about 30 feet.

Site No. 1 is an abandoned pit said to be over 30 years old dug into the gently sloping hill side of a cultivated field on the north side of the Belmont road. Faces of the pit are slumped and overgrown and the pit had up to two feet of water in it in October 1960 after a very dry summer. A ridge of sand crosses the pit about 1/3rd the distance from the lower side, probably the result of horse scraper excavation of the material from the bottom of the pit. The presence of water in the pit after a dry summer

is evidence of the ground water level of the area and indicates that there should be ample water supply for any future preparation plant.

Site No. 2 is a pit on the south side of the Belmont road about 1/4 mile closer to the village of Belmont. The north side is at road level; the south side exposes 10' to 12' of white sand, with occasional red clay lenses or layers over a length of, perhaps, 100 feet.

Sampling and Examination of Samples.

The pits were visited and 'grab' samples taken on October 14th/'60; the area about Site No. 1 was roughly surveyed on October 22nd and a program of below surface sampling layed out. Fewer auger for sampling was not available until February 18th/'61 at which time the field was snow covered and the exact sites of the proposed auger drilling could not be determined.

The attached sketch map shows the approximate location of the auger drilling and the log of each hole.

Representative samples from the auger drilling have been forward to the Department of Mines and Technical Surveys, Ottawa, for study. The balance of the samples are in hand at the Technical College Laboratories awaiting an opportunity for further examination.

Preliminary Examination
of 'Grab' Samples.

The 'grab' samples taken on Oct. 14th were dried and the following information obtained.

Physical Appearance:- The sands have a natural bonding material which yields a firm, slightly pink, cake on drying. No tests for bond strength have been made. Bulk density of the dried sand was determined at 100 lbs. per cubic foot.

Screen Analysis:- Standard screen analyses with Tyler screens in 'Retap' machine yielded the results shown in the attached table.

Microscopic Examination:- The screened products showed the coarser sizes (+ 35 mesh) to carry considerable amounts of a brownish red sugary soft sandstone which broke down readily under a slightly acid wash to yield a pinkish solution and grains of well rounded colorless quartz. The finer sizes (- 35 mesh) consisted, for the most part, of well rounded frosted quartz grains with increasing amounts of sub-angular grains as the particle size decreased. Much rock flour adhered to the grains in all sizes in spite of the mechanical agitation applied by the 'Retap' machine. This obviously accounts for the natural bonding power of the sands.

Quantity of Sand:

The series of 9 power driven auger holes as shown on the attached map indicate that may be at least 50,000 tons of white sands in the area adjacent to Site No. 1. They appear to form a 'pocket' in the red glacial(?) clays of the field. Absence of white sands in holes 2, 3, 5, 7, and 8, and its reported absence in the field to the east, suggest that it is a 'closed' pocket. The reported occurrence of white sands in the water well of the farm to the west and the known occurrence of sands in Site No. 2 further west are not likely to be a continuation of the sands but rather tend to indicate a series of 'pockets' in the surface clays of the area. Their approximate size is not determinable at present.

Uses for the Sand:

Little can be said as to the economic possibilities of these sands at this time. The Department of Mines and Technical Surveys has been asked to make some suggestions following what studies they may make. Further studies will be made at the Technical College when the laboratories are clear of student work. The natural bonding with rock flour suggests a market as moulding sand. The general pinkish color and red stain to acid wash tend to suggest that the sands are too high in iron

for a good glass sand but this may be corrected by proper preparation.

Recommendations:

This 'prospect' should not be abandoned at this time. The present licensed area is undoubtedly larger than the potential value warrants. Pits Nos. 1 and 2 can be taken as located in Mineral Claims O & P of Mining Tract 43, Ne., sheet 11360. Ample area would be retained if several licenses are obtained for the following mineral claims:

Mining Tract 43: Claims H, J, K, O, P, Q.

" " 44 " L, M, N, O.

" " 54 " A, B, C, F, G, H.

and a new license for

Mining Tract 53 Claims G, D, E, F.

making a total of 20 mineral claims in one block.

Respectfully submitted

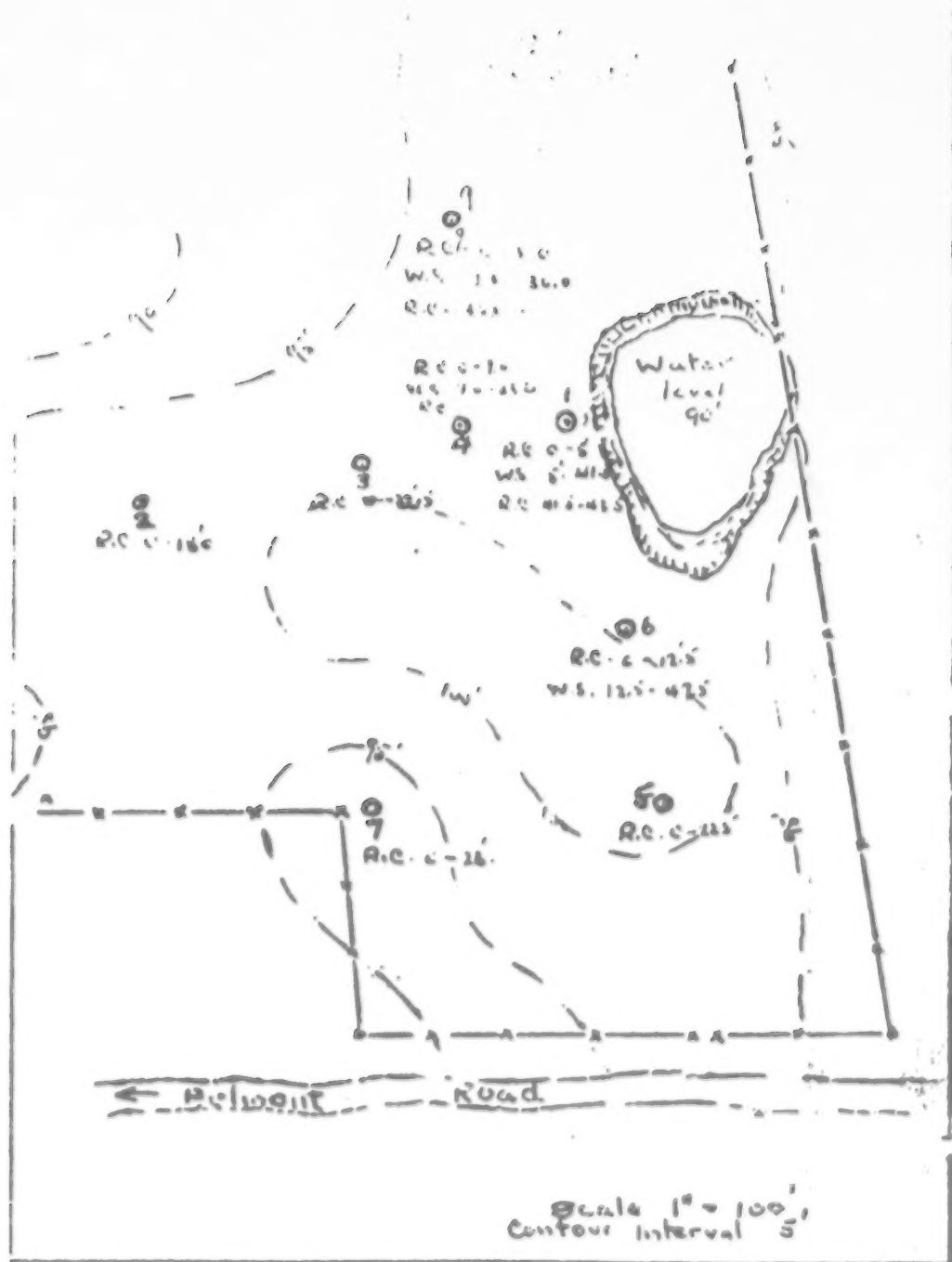
Alon T. Cameron
Alon T. Cameron
for Cameron & Cameron



TABLE NO. 1

Screen Analyses of Samples of White Sands
from Belmont, N.S.

Mesh Tyler	D. Hubley		Pit No. 1		Pit No. 2			
	June 27th		Wall		Floor		Wall	
	\$	Cum. \$	\$	Cum. \$	\$	Cum. \$	\$	Cum. \$
+ 8			0.8	0.8	0.2	0.2	0.1	0.1
+ 16	0.2	0.2	1.0	1.8	0.6	0.7	0.2	0.3
+ 20	3.4	3.6	3.1	4.9	3.1	3.8	3.4	3.7
+ 28	27.9	31.5	16.3	20.9	13.8	17.6	23.1	23.8
+ 35	35.1	66.6	24.8	45.4	19.1	36.7	37.3	66.1
+ 48	19.6	86.1	25.2	70.6	18.3	55.0	22.7	88.8
+ 60	3.0	89.1	11.4	82.0	12.3	67.3	1.9	90.7
+ 100	6.8	95.9	3.6	85.6	14.1	81.4	7.0	97.9
+ 150	1.2	97.1	1.3	86.9	8.0	89.4	0.8	98.4
+ 200	1.0	98.1	1.0	87.9	8.0	94.4	0.3	98.7
- 200	1.9	100.0	12.1	100.0	8.6	100.0	1.3	100.0
APA Fineness	33.12		61.98		60.29		33.16	
Class	7		5		5		7	
ASTM Fine. Med.		2.33		1.79		1.35		2.16



5



CANADA CEMENT LAFARGE LTD.

Research Laboratory
P O Box 398, Belleville, Ontario K8N 5A5

July 12, 1984.

MEMORANDUM

TO: G. Smith, Assistant Plant Chemist, Plant #6, Brookfield, CCL.

FROM: M. White, Research Chemist, Belleville Research Laboratory, CCL
D. Stevenson, Research Chemist, Belleville Research Laboratory, CCL

SUBJECT: PROJECT 84043, BROOKFIELD XRF STANDARDS - SAND ANALYSIS

Please find attached, Chemical Analysis data obtained by M. White and D. Stevenson on the following sands.

- (1) Davis
- (2) Chaleur ~~CCL 6~~ Sand - *fine particles*
- (3) Chaleur Large Particle *Chaleur Silice Sand - large particles*
- (4) Belmont CCL 6 Sand
- (5) N.S. Sand and Gravel - (Al White) *silica sand 1/4"*
- (6) N.S. Sand and Gravel - (Concrete Sand) *1/4"*

Please feel free to contact us if you have any questions.

DS:jp

D. Stevenson

Approved by:

[Signature]

cc: R.W. Suderman
H. Chen
S. Calmettes

PROJECT 84043
BROOKFIELD XRF SAND STANDARDS

Wet Chemical Analysis

	1	2	3	4	5	6
SiO ₂	82.48	98.04	95.72	90.48	98.32	86.36
Al ₂ O ₃ + TiO ₂ + P ₂ O ₅	6.94	0.55	1.30	4.21	0.64	5.39
Fe ₂ O ₃	2.66	0.33	0.43	1.52	0.26	2.03
CaO	2.00	0.38	1.12	0.76	0.29	1.72
MgO	1.00	0.02	0.08	0.07	0.02	0.80
Na ₂ O	0.88	0.00	0.00	0.10	0.00	0.74
K ₂ O	1.74	0.04	0.04	1.22	0.04	1.32
Total S	0.03	0.03	0.06	0.02	0.01	0.03
Loss @ 1050°C.	2.15	0.40	1.10	1.69	0.26	1.70

=====

TOTAL	99.89	99.79	99.85	100.07	99.84	100.09
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M. White

PROJECT 84043
BROOKFIELD XRF SAND STANDARDS

Wet Chemical Analysis

	1	2	3	4	5	6
SiO ₂	82.74	98.34	95.60	90.16	98.50	86.18
Al ₂ O ₃ + TiO ₂ + P ₂ O ₅	6.80	0.54	1.21	4.00	0.80	5.15
Fe ₂ O ₃	2.58	0.24	0.45	1.27	0.37	2.30
CaO	1.90	0.29	1.14	0.95	0.29	1.62
MgO	0.73	0.00	0.34	0.10	0.00	0.52
Na ₂ O	0.90	0.00	0.00	0.10	0.00	0.76
K ₂ O	1.84	0.04	0.04	1.36	0.04	1.44
Total S	0.03	0.01	0.07	0.02	0.01	0.01
Loss @ 1050°C.	2.11	0.35	1.16	1.75	0.17	1.73
=====						
TOTAL	99.63	99.81	100.01	99.83	100.18	99.71
=====						

D. Stevenson

An Investigation of
THE BENEFICIATION OF SILICA ORE
 submitted by
THE KEEVIL MINING GROUP LIMITED
 Progress Report No.1

Project No. L.R. 1230

NOTE:

This report refers to the samples as received.

The practice of this Company in issuing reports of this nature is to require the recipient not to publish the report or any part thereof without the written consent of Lakefield Research of Canada Limited.

LAKEFIELD RESEARCH OF CANADA LIMITED
 Lakefield, Ontario
 November 22, 1960

INTRODUCTION

On October 9, 1968, seven boxes of diamond drill core from a quartzite orebody were received at Lakefield Research and were assigned reference No. 6818635.

Mr. J.L. May of the Esvel Mining Group Limited instructed that composites of the ore be prepared and preliminary testwork carried out to determine if the iron content of the ore could be reduced to 0.04 percent in a product meeting glass sand specifications.

The usual size range required for glass sand is 100 percent passing 35 mesh with not more than 5 percent passing 150 mesh.

S U M M A R Y

Head Analyses

		<u>Composite I</u>	<u>Composite II</u>
Iron	(Fe ₂ O ₃)	0.60 percent	1.26 percent
Titania	(TiO ₂)	0.17 percent	0.29 percent
Alumina	(Al ₂ O ₃)	0.62 percent	1.08 percent
Lime	(CaO)	0.05 percent	0.23 percent
Magnesia	(MgO)	0.10 percent	0.46 percent
Soda	(Na ₂ O)	0.04 percent	0.05 percent
Potash	(K ₂ O)	0.084 percent	0.104 percent
Silica	(SiO ₂)	96.40 percent	94.80 percent

Crushing and Screening

To fall within marketing specifications, glass sand should be 100 percent passing 28 (35) mesh but not over 5 percent should be finer than 150 mesh Tyler. After carefully crushing in stages to minus 28 mesh, the minus 150 mesh fraction was removed and weighed. Over 1/3 of the total ore passed into this fine fraction.

Magnetic Separation: High-Grade Section (Composite I)

Iron-bearing grains are usually removed by high-intensity magnetic separation. In test 1 this was followed by scrubbing, desliming and flotation. The iron assays and weight recoveries after various stages are summarized below:

Summary - Continued

Stage	Weight, %	% Fe_2O_3
Head	100.0	0.64
+ 150 mesh	63.4	0.45
Non-Magnetica	55.6	0.23
Flotation Tailing	49.6	0.11

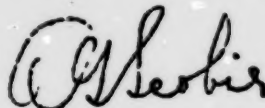
Desliming and Flotation - Composite II

A test based on desliming and extensive flotation was performed on the overall ore sample. Although 94 percent of the Fe_2O_3 was removed the final product, representing 45.7 percent of the original ore, assayed still 0.19 percent Fe_2O_3 .

Final Isodynamic Separation

The flotation tailing from test 1 was re-treated on an isodynamic separator at fixed field strength, slope and tilt. Although some iron bearing quartz grains were removed, the final assay of the improved product was still 0.10 percent Fe_2O_3 .

LAKEFIELD RESEARCH OF CANADA LIMITED



A.C. Scobie, P. Eng.,

Manager.

SAMPLE PREPARATION

The total ore represented the footages from 165 to 340 feet and was received in lots representing 10-foot sections. The high grade section was from 215 to 295 feet inclusive.

Composite of the individual 10-foot sections was prepared by jaw-crushing to minus 3/4 inch, rejecting 3/4, then cone-crushing and roll-crushing the remaining portion to minus 1/4 inch.

Composite I was prepared by combining 1/2 of the minus 1/4 inch material from 215 to 295 feet.

Composite II was prepared by combining 1/2 of the minus 1/4 inch material from 205 to 305 feet and included boundary zone material from 10 feet on either end of the high grade section.

<u>Footage</u>	<u>Zone</u>
205-215	Boundary Zone
215-225	
225-235	Low Iron Zone
235-245	
245-255	
255-265	
265-275	
275-285	
285-295	Boundary Zone
295-305	

Head Sample

Each composite was roll-crushed to minus 28 mesh, mixed thoroughly and a head sample was removed for analysis and the remainder was divided into 2000 gram charges for testwork.

	<u>Footage</u>	<u>% Fe₂O₃</u>
Composite I	215-295	0.60
Composite II	205-305	1.26

Sample Preparation - Continued

The following table shows the typical specifications for silica sand.

	CHEMICAL COMPOSITION	
	Flint Glass	Coloured Glass
Ferric Oxide (Fe_2O_3)	Not over 0.04 percent	Not over 0.15 percent
Titanium Oxide (TiO_2)	Not over 0.03 percent	Not over 0.10 percent
Alumina	Not over 0.50 percent	Not over 1.00 percent
Lime & Magnesia	Not over 0.10 percent	Not over 0.10 percent
Organic Matter	Trace Only	Not over 0.10 percent
Silica	Balance	Balance

For colourless (flint) glass, the ferric oxide and titanium oxide limits noted above are most critical.

Mesh Size (flint or coloured glass sand):

100 % through 20 or 35 mesh Tyler
Not over 5 % through 150 mesh Tyler

Test No. 1

Purpose: To remove iron-bearing impurities from glass sand by Lurgi magnetic separation followed by flotation on plus 150 mesh ore.

Procedure: Screen sample of minus 28 mesh ore on 150 mesh. Treat plus 150 mesh fraction in four passes through the Lurgi magnetic separator, then treat the non-magnetics by flotation to remove additional iron-bearing impurities.

Feed: 2000 grams of minus 28 mesh Composite I ore.

Conditions: 1st Lurgi Pass - 2.0 amps, 5/8 inch gap, motor setting No. 6.
2nd Lurgi Pass - 10.0 amps, motor speed reduced to No. 4.
3rd Lurgi Pass - 18.0 amps, same speed
4th Lurgi Pass - Same as 3rd but motor speed reduced to No. 2.

Flotation Conditions:

Stage	Reagents Added, pounds per ton				Time, minutes	
	Fatty Acid Emulsion	Aeroflote M-50	R-801	DF250	Cond.	Froth
Rougher Conc. 1	0.25	-	-	0.025	5	5
Rougher Conc. 2	-	0.06	-	-	1	2
Rougher Conc. 3	0.13	-	0.10	-	3	3

Stage
Flotation Cell
Speed: r.p.m.

Rougher Flotation
500 gram D-1
1300

Test No. 1 - Continued

Metallurgical Results

Products	Weight %	Assays, % Fe ₂ O ₃	% Distribution % Fe ₂ O ₃
1 1st Lurgi Magnetics	2.30	4.75	17.00
2 2nd Lurgi Magnetics	2.89	1.13	5.08
3 3rd Lurgi Magnetics	1.39	0.56	1.21
4 4th Lurgi Magnetics	1.23	0.75	1.44
5 Flotation Conc. 1-3	5.67	1.23	10.85
6 Slimes on Flotation Tail.	0.29	1.54	0.70
7 Flotation Tailing	49.63	0.11	8.49
8 Minus 150 mesh	36.60	0.97	55.23
Head (calculated)	100.00	0.64	100.00
Direct Head		0.60	

Calculated Grades and Recoveries

Products 1 + 2	5.19	2.73	22.00
Products 1 to 3	6.58	2.27	23.29
Products 1 to 4	7.81	2.03	24.73
Products 1 to 5	13.48	1.70	35.58
Products 5 to 7	55.55	0.23	20.04
Products 1 to 7	63.40	0.45	44.77

Test No. 2

Purpose: To study the removal of iron bearing impurities from glass sand by desliming and flotation at a coarse size.

Procedure: Pulp a sample of Composite II ore in water, agitate and siphon fines through a 150 mesh screen. Repeat four times to deslime and remove minus 150 mesh ore. Float iron-bearing impurities with a fatty acid emulsion, petroleum sulphonate collectors and fuel oil in an acid circuit and with wine collectors.

Feed: 2000 grams of minus 10 mesh Composite II.

Conditions:

Stage	Reagents Added, pounds per ton							Time, min.		pH
	H ₂ SO ₄	R-801	R-825	DF250	Z-6	Dumect T	Ethomoon	Cond.	Froth	
Ro. Flotation	-	-	-	-	-	-	-	5	-	-
Ro. Conc. 1	-	-	-	0.02	0.05	-	-	1	4	-
Ro. Conc. 2	0.5	-	-	-	-	-	-	3	-	4.3
	-	0.30	0.10	-	-	-	-	2	2	-
Ro. Conc. 3	-	0.30	0.10	0.02	-	-	-	2	2	-
Ro. Conc. 4	-	-	-	-	-	0.10	-	1	3	-
Ro. Conc. 5	-	-	-	-	-	-	0.02	1	5	-

Stage	Agitation	Rougher Flotation
Equipment	1000 3 Glass Bowl	1000 gram D-2
Speed: r.p.m.	Dyna Drive	1200

Metallurgical Results

Products	Weight %	Assays, % Fe ₂ O ₃	% Distribution % Fe ₂ O ₃
1 Rougher Concentrate 1	11.88	5.43	46.51
2 Rougher Concentrate 2	2.29	2.11	3.48
3 Rougher Concentrate 3	3.50	0.54	1.36
4 Rougher Concentrate 4	5.25	0.74	2.81
5 Rougher Concentrate 5	45.66	0.19	6.26
6 Flotation Tailing	9.75	0.94	6.61
Slimes + Minus 150 mesh	21.67	2.11	32.97
Head (calculated)	100.00	1.39	100.00

Calculated Grades and Recoveries

Products 1 + 2	14.17	4.89	49.99
Products 1 to 3	17.67	4.03	51.35
Products 1 to 4	22.92	3.28	54.16
Products 1 to 5	68.58	1.22	60.42
Products 1 to 4 + 6	32.67	2.58	60.77
Products 1 to 6	78.33	1.19	67.03

Test No. 3

Purpose: To determine if additional iron-bearing particles could be removed from the flotation tailing of test 1 by careful Frantz magnetic separation.

Procedure: Pass the flotation tailing through the Frantz isodynamic separator and re-pass the non-magnetics at the same settings. The final non-magnetics were assayed for Fe_2O_3 .

Feed: 105 grams of flotation tailing from test 1.

Conditions:

Frantz Isodynamic Separation

Settings	Amperes	Forward Slope	Tilt (Sideways)
1st Pass	1.5	35°	20°
2nd Pass	1.5	35°	20°

Metallurgical Results

Products	Weight %	Assays, % Fe_2O_3	% Distribution	
			% Fe_2O_3	Overall % Fe_2O_3
1st Magnetics	2.96	-	-	-
2nd Magnetics	2.00	-	-	-
Non-Magnetic	95.04	0.10	86.36	7.34
Head (Direct)	100.00	0.11	100.00	8.49

Investigation by: D.M. Wyszomil
J. McCarthy

Lakefield Research of Canada Limited
Lakefield, Ontario
November 22, 1968 / tmg

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WORTH ULICA CO. LT
No N. N. Y.

41- 0063)

RECEIVED
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Letter Report
Preliminary Comments
on

nda

CAR'S ADDRESS
BEHRE DOLBEAR

TELEPHONE
OI 4-8830
AREA CODE 212

BEHRE DOLBEAR & COMPANY

MINING, GEOLOGICAL AND METALLURGICAL CONSULTANTS

ELEVEN BROADWAY
NEW YORK, N. Y. 10004

CHAR. H. BEHRE, JR.
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ASSOCIATES:
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A. NELSON SAYRE
R. W. McALLUM

June 1, 1965

Mr. Peter L. Marmion
Northern Silica Co., Ltd.
c/o Marland Stone Corporation
641 Lexington Avenue
New York, New York 10022

Dear Sir:

These are strictly preliminary comments on a deposit of quartzite, in Nova Scotia near Yarmouth, which is being considered for development for chemical uses or glass-making. The attractive qualities of this deposit are its relative purity, its probably large tonnage, and its nearness to shipping facilities at Yarmouth, Nova Scotia, especially for Eastern Seaboard trade. Moreover, the Government of Nova Scotia is hopeful of establishing a glass plant in the relatively depressed Yarmouth area and will help all it can. Before its economic feasibility can be assured, however, four facts must be clearly established, which can at present only be inferred as probably favorable. These are: (1) a minimal tonnage, preferably about three million tons; (2) a grade that is acceptable as it stands or is subject to economical treatment to raise it to a suitable level; (3) the possibility of crushing and screening to satisfy customary specifications; (4) an adequate market.

Requirements of Glass and Chemical Quartz Sources

For glass making and chemical uses a sand, sandstone, quartzite, or vein quartz deposit must have high purity and a relatively narrow size frequency. These specifications must be maintained at a constant level throughout any given long-term contract, such as will be desirable. According to T. D. Murphy (Industrial Minerals and Rocks, published by the American Institute of Mining, Metallurgical and Petroleum Engineers, 3^d Ed., 1960, pp. 764-765) the usual requirements set by glassmakers are that essentially all of the material must pass through a 30-mesh screen and not more than 2 per cent may pass through a 140-mesh screen, the size requirements being related to uniform melting. Grain shape does not appear to be a general specification factor. The common impurities are alumina and Fe_2O_3 ; for flint glass the Fe_2O_3 content cannot exceed 0.02 to 0.025 per cent; for amber, it must lie between 0.05 and 0.08 per cent. The alumina (Al_2O_3) content ranges up to 0.2 per cent, the calcium and magnesium oxides together must usually be not more than 0.05 per cent, and the alkalis 0.01 per cent, according to the reference cited.

Industrial silica for chemical uses must meet about the same specifications. Besides being used for making ceramic products, it is a necessary raw material for sodium silicates and silicon carbide, but individual practice varies somewhat with the desired product.

It will be seen from the above, however, that (1) grinding tests and (2) milling for purification followed by analyses to test the chemical composition of the milled product are thus basic quality requirements and the necessary tests should be carried out simultaneously or before any further drilling is undertaken to establish quantity.

Available Facts as to Yarmouth Deposit

The deposit in question consists of a very clean, well recrystallized hard quartzite, which crops out intermittently from Lake George, about 11-1/2 miles north-northeast of the town of Yarmouth, in Yarmouth County, Nova Scotia, to Chagoggin Point, 3-1/2 miles northwest of Yarmouth. The quartzite is little seen at the surface, being almost everywhere covered by glacial till, with many large boulders. The till is not consolidated and in general is about 20 feet thick. It should be readily stripped, except for the occasional breaking of a large boulder with powder. The length of the probably continuous outcrop is, as nearly as can be inferred, about 11 miles if the northernmost end is taken to be at Lake George, but exposures are actually visible in only three places in this distance. One of these is in a road cut near where the highway immediately west of Lake George cuts a low hill in the section (1 square mile) designated 93 on Sheet 20-Q-16-D of the Topographic Map of Nova Scotia, as published by the Department of Mines of the Province of Nova Scotia. ~~The second is in a road cut and on the opposite side of the road in the section (1 square mile) designated 18 on Sheet 20-Q-16-D, about 200 feet north of Foote Corner.~~ The third is in the old quartzite quarry on Chagoggin Point in the section (1 square mile) designated 63 on Sheet 20-Q-16-A of the Topographic Map of Nova Scotia. The last described is on land held by the Dominion Iron and Steel Company which quarries the quartzite for silica brick, at an average rate of about 1500 tons per year; this quarry land is not open to use by Northern Silica and is of importance to the present report only insofar as it affords a clue as to the nature of the quartzite and the possible structure of the stratum involved.

The quartzite is part of a series of Paleozoic strata and is referred to the White Rock formation of Ordovician or Silurian Age. Above it are highly altered volcanic rocks, now converted to dark schists, slates and gneisses; below it is the Halifax series - slates, again mainly argillites and schists, not readily distinguished from the formation that overlies the quartzite. The entire sequence of rock is considerably folded, dips ranging from 65° to 90° N.W. It may also be faulted, thus producing irregular discontinuities, but of this there is no positive evidence. In the few exposures where bedding was inferred with reasonable confidence, the prevailing strike is northeast, averaging N. 35° E. In an attempt to trace the line of outcrop, rough tranverses were run on all roads which cross this assumed trace, from the western shore of Lake George to Chagoggin Point, due west of Halifax.

Because of the heavy cover, data on the continuity of the bed of ~~quartzite are based on the three exposures and on three Diamond Drill cores~~ available from holes drilled by the Nova Scotia Department of Mines, to which indebtedness for this information and for systematic analyses of the quartzite in the cores is herewith gratefully acknowledged.

Quantity and Quality of Product as Bearing on Use

The material described is a relatively very clean quartz sand, well cemented with secondary silica to the point where it can be described as a quartzite. It is very faintly laminated in some parts of its thickness but rarely are there differences visible in its composition as related to bedding, and even such differences are slight. There is some staining with limonite on joint and bedding surfaces but these seem to be prominent

only near the present surface of the land, not in the cores. In a few places thin laminae of schistose rock are interbedded, notably at the quarry on Chagoggia Point, where the rock on the dump clearly shows such slaty or schistose interbeds, estimated to aggregate at most 5 feet in thickness.

The country rock in the region was diamond-drilled in nine localities and three of the four resulting cores containing quartzite were visually examined, logged and analyzed. The descriptions of these cores are not detailed here but the location of the cores and their analyses are given below.

Diamond Drill Hole No. 1 was drilled just west of Island Pond (Ukley Lake) at an angle of 45° from the horizontal and in a downward slope in the direction N. 48° W. (312°). It contained white quartzite with a few disseminations and tiny veinlets of pyrite and possible pyrrhotite and a very few fine laminae of micaceous schist. The quartzite in this core was analyzed, yielding the following results.

TABLE 1

Analyses of Quartzite in Core
of Diamond Drill Hole No. 1

<u>Core No.</u>	<u>Footage</u>	<u>Per Cent SiO₂</u>	<u>Per Cent Fe</u>
1	123-130	95.11	1.60
2	130-140	92.34	1.80
3	140-150	84.07	3.53
4	150-160	92.41	1.72
5	160-170	98.23	1.26
6	170-178	97.48	1.23
Total Length in core	55 feet	Average <u>93.27</u>	<u>1.866</u> ?

As nearly as could be determined, the bedding in this core formed an angle of about 30° with the long dimension of the core, from which it is inferred that, consistent with similar observations made elsewhere in this study, the bed dipped 70° - that is, almost vertically. If this is correct, the bed has here a total thickness of only 26 feet, which is so improbably low a figure, compared with data obtained in the other two drill cores, that it is assigned either to abnormal thinning or to faulting.

About 300 feet northeast of Diamond Drill Hole No. 1, Drill Hole No. 2 was put down. Its core was not available for examination but is described as containing a length in the core of 87 feet of rock similar to that of Diamond Drill Hole No. 1. If the relation of bedding to core length and if the dip are both about the same, as in Diamond Drill Hole No. 1, the total thickness of the bed here is about 45 feet - again low compared with measurements made farther north.

Diamond Drill Holes Nos. 3, 4 and 5 showed only dark, schistose rock and penetrated no quartzite. These holes were put down at three points relatively close together and all about 1-1/2 miles east of the crossroads at Pembroke Shore, in Section 7, Sheet 20-C-16-D. All three were at an angle of 45° from the horizontal and all were inclined downward in the direction N. 48° W (or 312°).

Diamond Drill Hole No. 6 was put down after the quartzite had been exposed nearly in building the road (Lake George Road) parallel to the western shore of Lake George, about 200 feet west of the shore of the lake. It was drilled east of the road, inclined in a southeast direction, at an angle of 45° from the horizontal. Examination of the core showed that its long dimension is approximately at right angles to the

bedding; the length of quartzite penetrated in the drill hole should, therefore, approximate the true thickness of the quartzite at this locality. Results of analyses of the quartzite in the core are presented in Table 2.

TABLE 2

Analyses of Quartzite in Core
of Diamond Drill Hole No. 6

<u>Sample No.</u>	<u>Footage</u>	<u>Per Cent SiO₂</u>
1	70-85	92.91
2	85-100	98.23
3	100-115	95.21
4	115-130	98.75
5	130-145	93.04
6	145-160	97.46
7	160-175	96.94
8	175-190	98.21
9	190-205	95.93
10	205-220	97.72
11	220-235	98.51
12	235-250	98.91
13	250-265	98.11
14	265-280	88.84
15	280-295	92.67
16	295-310	85.27
17	310-325	96.43
Total Length in core	255 feet	Average 95.48

Diamond Drill Holes Nos. 7 and 8 were both in schist, penetrating no quartzite. They were drilled about 250 feet due south of Diamond Drill Hole No. 9, Hole No. 7 being directed downward toward the northwest and Hole No. 8 downward toward the southeast at 45° from the horizontal. Their failure to intersect quartzite, in view of the fact that it was found in Diamond Drill Hole No. 6 and Diamond Drill Hole No. 9 (see below) is at-

tributable either to a fold which carried the quartzite bed north of these holes or (more probably) to a fault that displaced it transverse to the regional strike or trend of the beds.

Diamond Drill Hole No. 9 was started about 280 feet S. 15° W. of the collar of Drill Hole No. 6, at a point west of the road that is roughly parallel to the western shore of Lake George. It was inclined at 45° from the horizontal in a southeast direction and penetrated a length in the core of 166 feet of white quartzite similar to that found in Drill Hole No. 6. Again the core indicates that the measured length of the quartzitic beds is approximately their total actual thickness. Table 3 gives measurements and analyses of this core.

TABLE 3

Analyses of Quartzite in Core
of Diamond Drill Hole No. 9

<u>Sample No.</u>	<u>Footage</u>	<u>Per Cent SiO₂</u>	<u>Per Cent Fe</u>	<u>Per Cent Al₂O₃*</u>	<u>Per Cent CaO*</u>	<u>Per Cent MgO*</u>
100	22-35	98.51	0.45	-	-	-
101	35-50	98.91	0.37	0.41	Nil	0.11
102	50-65	99.02	0.29	0.11	"	0.26
103	65-80	99.17	0.34	0.09	0.09	0.17
104	80-95	98.11	0.64	0.51	N.D.	N.D.
105	95-110	98.74	0.45	0.14	0.21	0.23
106	110-125	98.85	0.47	0.32	N.D.	0.18
107	125-140	98.98	0.41	0.21	0.14	0.12
108	140-155	97.31	0.31	0.66	N.D.	N.D.
109	155-170	99.13	0.33	0.13	N.D.	0.23
110	170-180	98.92	0.42	0.19	N.D.	N.D.
111	180-188	97.21	1.35	0.13	N.D.	0.56
<u>Total Length in core</u>		<u>166 feet (av.)</u>	<u>98.57</u>	<u>0.57</u>	<u>0.28</u>	<u>.09</u>
					<u>.09</u>	<u>.023</u>

*Averages in these columns based only on the analyses where the values were actually determined, not including those marked "-" or "N.D."

Reserves and Recommendations

In view of the strike of the beds, where observed in the outcrop on the road west of Lake George and near Foote Corner, as well as the exposures in the quarry on Chagoggin Point, it is fairly clear that the quartzite is a continuous stratum, probably of variable thickness, extending from the exposure near Lake George for a distance of about eleven miles to the quarry and finally into the sea at Chagoggin Point. Of this distance, at least ten miles are controlled or will shortly be so by Northern Silica. Assuming an average thickness of 100 feet (a conservative estimate), a length along its strike or trend of about 50,000 feet, and a quarry depth of 50 feet in the nearly vertical beds, the tonnage would be approximately 20 million tons, but these figures are very uncertain.

The outcrop may be longer because of folding, the bed is thicker than 100 feet in Diamond Drill Holes Nos. 6 and 9, and the depth of quarrying can well be greater than 50 feet. These factors, if present, would all favor a larger reserve. On the other hand, the bed may be faulted and thus made available for only a part of the 10 miles here assumed; the thickness may be greatly reduced at least locally, as suggested by Diamond Drill Holes Nos. 1 and 2; and the dip may change, so as to produce too heavy an overburden to permit quarrying with vertical walls against the useless rock to a depth of even as much as 50 feet. All these factors, if present, would materially reduce the total reserves.

In short, to date reasonable confidence can only be placed in reserves lying between Diamond Drill Holes Nos. 6 and 9. These give a length of 280 feet and a thickness averaging 210 feet; assuming a quarry depth of 50 feet, the total reserves that can be cited with a fair degree

of confidence are as follows:

(280 x 210 x 50) divided by 12 (the factor for converting cubic feet to tons) = 245,000 tons.

This is all that can be reasonably assumed from the data now available, though extrapolation to at least 10 times that figure might be possible if continuity for the quartzite bed from Diamond Drill Hole Nos. 1 and 2 to Diamond Drill Hole No. 9 were demonstrated.

Because of these facts, the initial placing of at least 3 and possibly 4 more holes would be desirable to ascertain position and thickness of the quartzite between Diamond Drill Hole No. 6 and Diamond Drill Holes Nos. 1 and 2. Each such hole would probably be extended to a point 300 feet from the surface. The cost quoted on May 24 by the Provincial Department of Mines was \$7 - \$8.00 per foot. The cost of later, necessary drilling could be charged against profits.

Specifications and Recommendations

Attention is directed to the specifications, however generally phrased, given near the beginning of this letter. Few of the individual analyses made by the Nova Scotia Department of Mines come up to standard specifications, as will be seen from a study of Tables 1, 2, and 3. It is imperative therefore that careful analyses are made of all cores available after a milling company or other competent consultant has demonstrated that the raw material as mined, quarried, or cored can be cleaned by practical and economical methods to the requisite standards. This will require some planning, adequate testing and careful interpretation by the company consulted.

These steps, though expensive and time consuming, will avoid further larger expenditures until the possibility of using (and hence of marketing) the finished crushed rock has been demonstrated. They will also furnish concrete figures as to the cost of milling and can serve as the basis for estimating the cost of the necessary mill, if Northern Silica decides to operate the quarry itself.

Advantages of the Proposed Operation

Attention should be directed, however, briefly to two especially advantageous factors:

- (1) The location with shipping facilities at Yarmouth and a trucking distance of only 10 to 12 miles for a quarry located within the area. This offers especially cheap transportation to southeastern Canada as well as to the northeastern United States.
- (2) The Provincial Government has given various kinds of assurance that the project will be favored and assisted. It has quoted drilling charges at cost; has removed from government control a large section of land adjoining Lake George in the interest of Northern Silica; and has issued prospecting permits for a total of some 16 square miles, to the same end.

Recommendations, in Brief:

In view of the foregoing, three steps are recommended, to be begun successively in this order:

1. Reserving for prospecting by Northern Silica, the following one-mile-square sections:

Nos. 6, 7, 8, 19, 54 and 67 of Sheet 20-O-16-B

and Nos. 90, 103, and 104 of Sheet 20-O-16-A.

The sheets referred to are numbered as indicated and are issued by the Department of Mines of the Province of Nova Scotia. These reservations, together with those already assigned to Northern Silica, cover the area possibly underlain by the quartzite and should effectively exclude competition - at least for the small trucking distance indicated.

2. Careful checking of the acceptability of the raw material as to:

- (a) Its adaptability to crushing to the requisite screen sizes, these, if possible, to be obtained from specifications furnished by purchasers of the product, and
- (b) The possibility of cleaning it so that the occasional crystals of iron sulphide seen in the core, the occasional discoloration of the rock by hydrated iron oxide stains seen at the outcrop and locally in the core, and the aluminum and calcium and magnesium oxides (probably present as carbonates) can be reduced to suit the specifications of probable purchasers.

3. Additional core drilling to more accurately outline:

- (a) the position, (b) the true thickness and (c) the

Should be done by purchaser but has been your assistance.

BEHRE DOLBEAR & COMPANY, INC.

13.

attitude (or dip) of the quartzite bed. This should also furnish more data as to the composition and the behavior on grinding of the run material as mined.

Very truly yours,

BEHRE DOLBEAR & COMPANY, INC.

Chas. H. Behre, Jr.
Chas. H. Behre, Jr.
Geologist

(2)

MS120250

41- 2-0804

Report 54 H
NTS 20-0-16

ASSISTANT LIAISON REPORT
on the
LAK GEORG SALIC

by

Matthew Wlecha

May 12, 1969

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Appendix

Diamond Drill Log Holes Nos. 1 - 5, (inclusive)
 Expenditures
 Metallurgical Report

Illustrations

Property Map	1" : 1/2 Mile
Geology Block A	1" : 400'
" Block B	"
" Block C	"
Magnetic Survey Block A	"
" " Block B	"
" " Block C	"
Detail Geology, LI 39N -151 W	1" : 100'
Detail Page. Survey	"
Vertical Section L72N	1" : 50'
" " L 149W	"

INTRODUCTION

THE PROPERTY

The Lake George Silica Property consists by the following claims, registered in the name of Iain Downie:

Lie. No.	Tract.	No of claims	Ref. Map
5286	88-E 1/4	4	20-O-16A
5287	89	16	"
5288	103-W 3/4	12	"
	104-E 1/4	4	"
5289	104-W 3/4	12	"
	105-E 1/4	4	"
5290	6-W 1/4	4	20-O-16D
5291	7	16	"
5292	17-E 1/2	8	"
5293	18	16	"
5294	19	16	"
5295	29-W 1/2	8	"
5296	30	16	"
5297	31	16	"
5298	42-E 1/2	8	"
5299	43	16	"
5300	44	16	"
5301	52-W 1/2	8	"
5302	53	16	"
5303	54	16	"
5304	67-E 1/2	8	"
	68-W 1/2	8	"
5305	68-E 1/2	8	20-O-16D
	69-W 1/2	8	"
5306	69-E 1/2	8	"
	70-W 1/4	8	"
5307	73-W 1/2	8	"
5309	77	16	"
5310	92-E 1/2	8	"
5311	99	16	"
5312	100	16	"
7732	6	16	"

In addition, parts of tracts Nos. 76, 93 and 94, previously held by Mr. E. J. McLeave, are in the process of being acquired in I. Downie's name.

Location and Access.

The claims lie north and west of the town of Yarmouth, on the southwest coast of Nova Scotia. The property is easily accessible by numerous roads and highways.

General Geology

The Lake George area is underlain by tightly folded lower and Upper Ordovician or Silurian rocks which strike predominantly $N20-30^{\circ}$ E. The oldest rocks are slates and minor argillites belonging to the Halifax formation. These are conformably overlain by the White Rock formation which consists of quartzites, with minor slates, calc-sites, and amphibole-feldspar gneisses.

The economically important White Rock formation forms part of the west limb of a syncline, the axis of which strikes $N20-30^{\circ}$ E, and passes through the Yarmouth harbour. The quartzite outcrops at several places on the property, and probably extends from the coast at Chegegin Point northeastward toward Lake George over a total strike-length of 13 miles. The formation is also present in the east limb of the syncline, and outcrops northeast of Yarmouth, near the village of Brooklyn, where it can be traced over a strike length of 3 miles.

The best exposure occurs at Chegegin Point, where the quartzite is interbedded with slate and amphibolite in a broken section of 210 feet in thickness, (G.S.C. Map 44-1963). The northeast continuation of the quartzite band is inferred mainly by the occurrence of numerous boulders, and by relatively few outcrops.

The presence of the quartzite southwest of Lake George was established by diamond drilling, carried out by the Nova Scotia Government in 1963.

The main purpose of the work programme carried out in 1968 was to (1) determine the continuity and the exact position of the quartzite band, (2) determine its thickness, and (3) obtain samples for metallurgical testing. To accomplish the above objectives, the following work was carried out.

WORK DONE

1. Cutting and Surveying of a base line consisting of two sections:
a. northeast from Chagaggin Point for a length of 18,150 feet. b. southwest from Lake George for a length of 6,200 feet.
2. Cutting of 6.9 miles of picket lines spaced at 800 ft. intervals, and oriented at right angles to the base line.
3. A magnetometer survey was carried out over the entire grid, with readings taken at 50' intervals; at 25' intervals wherever necessary.
4. Geological mapping was carried out over the entire area covered by the picket lines, on a scale of 1" : 400', Detailed mapping (1" : 100') was done between lines 137N and 151 N.
5. Diamond Drilling. Six holes were drilled with AXT core, for a total of 1,354 feet.
6. Metallurgical tests were carried out on the quartzite encountered in drill hole #1. The results of the tests are described in a separate report.

Results

Magnetometer Survey. The results of the magnetometer survey were discussed in detail in Report No. M^h by Sharpley, (1968), and only a brief summary will be given here.

The survey indicated the presence of a prominent magnetic low which extends for a length of 14,000 feet northeastward from Chaggin Point. The magnetic low ranging to -2,600 gauss extends over an average width of 200 feet, and is flanked by a prominent high to the east, which ranges up to + 3,900 gauss over an average background of +400 gauss.

South of Lake George, (grid "C"), the magnetic low is less prominent, and the magnetic appear to be disrupted, possibly as result of folding or faulting.

Surveys along three traverses in the area between the two parts of the base line (Block "B") failed to indicate the presence of the magnetic low.

In addition, a detailed magnetic survey was carried out between lines 139+00N and 151+00N in order to establish a correlation between the magnetic low and the known outcrop of the quartzite band. The results of this survey established beyond any doubt that while the magnetic low shows a close spatial relationship with the White Rock formation, the quartzite band is not the source of the anomaly. The cause of the anomaly remains unknown.

Pneumonic Drilling. Six holes were drilled on the following locations:

<u>Hole No.</u>	<u>Location</u>	<u>Asin.</u>	<u>Dip</u>	<u>Length</u>
1	Block B, 149+00N, 0+30W	306°	-35°	400.0'
2	Block A 72+00N 4+45W	"	"	212.0'
3	Block A " 0+00W	"	40°	420.0'
4	Block A " 7+40W	"	"	185.0'
5	Block A " 7+40W	"	90°	75.0'
6	Block C 15+35E 11+30W	302°	-45°	72.0'
Total Footage				1,334.0'

Logs and sections of holes Nos. 1 - 5, (inclusive), are enclosed with this report. Hole No. 6 was not logged in detail.

Of all the above holes, only No. 1 and No. 4 encountered the quartzite band. Hole No. 5, was drilled from the same location as No. 4 in order to determine the position of the hanging wall.

Geological Mapping. proved unsuccessful in determining the exact position of the quartzite horizon along most of its inferred strike-length. The quartzite outcrops rarely, and detailed mapping of the numerous quartzite boulders is not always reliable; the boulders have been transported by glaciation, as well as by farmers to clear their fields, and build stone fences. The average direction of glacial movement was probably due south, but boulders of quartzite are found on both sides of the quartzite horizon.

Discussion of the results. From the drilling data as well as from the exposure of the quartzite on the coast at Chagoggin Point it appears that the White Muck formation consists of several sections of quartzite which are separated by amphibolites, slates and schists. The width of these rocks ranges from one foot to 20 feet or more, and judging by the distribution of quartzite boulders may be considerably greater.

The true total width of the quartzite, including the intervening rocks ranges from 210' (on the coast) to 140' in holes No.1 and No. 4, and to at least 140' south of Lake George, as determined in hole No. 6 drilled by the U.S. government.

The dip of the quartzite ranges from near-vertical to 70° east.

An interesting outcome of the diamond drilling was the discovery of a narrow graphitic bed associated with the quartzite formations in holes No. 1 and No. 4. Attempts were made to use the graphitic bed as a guide to the quartzite by tracing it with C.P., but the results were negative.

SUMMARY AND RECOMMENDATIONS

Before diamond drilling is resumed, an exploration method must be found by which the quartzite formation could be traced accurately. Neither magnetic nor C.P. surveys provide the answer. Geological mapping, while still useful as a general guide, is not sufficient.

It is recommended that various geophysical techniques, including radio and resistivity be employed in areas of known occurrence of the quartzite. If a satisfactory method is found, a survey will have to be carried out over the entire grid.

An alternative method by which the quartzite bed might be located is to drill a series of short (25' - 30') vertical test holes at 100' intervals along east-west picket lines. This could be done without setting up a tripod, and at a lower cost per foot than for drilling down so far.

Respectfully submitted,

Matthew Bloeba

REFERENCES

- Sharpley, F.J., 1967: Report on George Lake Silica, (March 1967)
1968: Report on George Lake Silica Deposit
Report JON, March 2, 1968
1968: Exploration Report, George Lake Silica,
Report JLN, April, 1968
Geol. Survey Canada, Map 44 - 1966

DIAMOND DRILL LOG

Hole #1

Lake George Sillies

Location: 149°00', 0°50'

Started: Sept. 16, 1968

Dip at collar: -35°

Completed: Sept. 19, 1968

at 200'

Logged by M. Bloeba

at 400'

Striked: 163° (due pocket west)

Core #1-01

Depth: 400.0'

- 0.0' Overburden
- 0.0'
- 15.0' porphyry. (?) grey, well banded. (25-30° c.n.); 15-20% rounded, pale brown phenocrysts, (?) of feldspar, (1-5mm), in a fine gr'd matrix. possibly a coarse volcanic?
- 26.0'
- 26.0' QUARTZ-AMPHIBOLITE, dark green, soft, schistose @ 25° c.n., with locally well developed amphibole crystals; and inclusions of quartz, reddish brown material, parallel to foliation. Interbedded with quartz-sericite schist at 47.5-50.0'; 74.7-79.7'; 95.7-100.4'. The quartz-sericite schist is grey, well schistose, micaceous, fairly hard. Foliation mostly at 10-15° c.n. from 44' on.
- 121.7'
- 121.7' AMPHIBOLITE-QUARTZITE, dark green, gneissose at 25-30° c.n., 20-40% amphibole, dark green, epidotized matrix. Contains numerous micaceous bands.
- 134.5'
- 134.5' Gneissite Schist, as before, but schistosity not as well developed. Locally grading into dark grey, qtz-rich schist, as at 47.5'. Note qtz stringers at 142.1'. (?) Lost core at 167.5-169.0'.
- 170.0'
- 170.0' AMPHIBOLITE-QUARTZITE, as at 121.7, but coarser grained, and foliated at 40° c.n.; numerous micaceous bands.
- 176.0'
- 176.0' Gneissite Schist, as before, sharp contact, schistosity at 40° c.n. Lost core at 172.2-184.0'
- 186.5'
- 186.5' QUARTZ VEIN, coarse, white, locally fractured, and min'd with 1-2% pyrite.
- 194.0'
- 194.0' Gneissite Schist, faintly banded at 50° c.n. Irregular contact, with qtz veins extending to 194.0'. Occasional narrow qtz stringers. Impure.
- 209.0'
- 209.0' Quartz veins, irregular.
- 210.5'
- 210.5' CHLORITE-SERICITE-QUARTZ-SCHIST, dark greenish grey, well schistose at 30° c.n., soft. Fr. pyrite along fractures.
- 215.0'

- 215.0' WHITE QUARTZITE. First 4' locally still impure. Becomes fairly pure from 215' on, but narrow, (1mm) bands of impure material still present at 1-2" intervals. Lost core 225.4 - 227.0'
- 227.0' white, pure quartzite; occasional traces of pyrite along fractures. Lost core at 247-249.5.
- 292.0' Quartzite gradually becoming light grey due to impurities. Lost core at 296.5-297.5'.
- 297.55, white quartzite, with dark patches at 299-301', and grey banding at 302.5 - 304.0'
- 304.0'
- 304.0' GREY QUARTZITE, with only minor white patches.
- 312.0'
- 312.0' QUARTZ-EPIDOTE SCHIST, abrupt contact at close to 0° c.n. Few small quartzitic inclusions near contact. Locally spotted with 1-2mm round, brownish specks; schistosity at 0°-5° c.n.
- 315.4 Lost core.
- 317.2
- 317.2' GRAPHITE SCHIST, charcoal grey, well schistose at 5-10° c.n., with local crenulations. Possible fault. Min'd with 5-7% pyrite, (po-?) along seams parallel to foliation. Locally broken up core.
- 326.0'
- 326.0' QUARTZ EPIDOTE CHLORITE SCHIST with local development of coarse amphibole, and micaceous bands. Foliation at 0-10° c.n.
- 342.0'
- 342.0' QUARTZ-BICA SCHIST, dark grey, as at 47.5'. Well developed schistosity at 0-10° c.n.
- 346.5 Grades into impure quartzite.
- 349.5
- 349.5' CHLORITE-BICA SCHIST, biotitic, fairly coarse, good foliation at 15° c.n.
- 352.0'
- 352.0' GRAY QUARTZITE, impure, micaceous, with good foliation at 5° c.n.
- 359.0' Irregular white quartz veining, with inclusions of the above schist.
- 3610.0'
- 3610.0' GREY QUARTZITE
- 400.0'
- 400.0' End of hole.

104.0 201.7 continued

The rock is uniform but for local variations in the relative amounts of amphibole and biotite.

Pyrite crystals are common

Occasional chalcopyrite is encountered. 156.0 ft. gneissosity at 85° to e.s.

177.8 - 182.6 core lost.

201.7 212.0 Amphibole Schist

as for 25.0-62.6

- free of epidote

212.0 End of Hole

PROPERTY: George Lake Silica

HOLE No.: 3

LOCATION: Block "A"
Lat.: 72-00N
Dep.: 0-00

AZIMUTH: 335°
Dip: Collar 40°
" 300' 35°
" 400' 35°

DATE: Oct. 1948

FINAL DEPTH: 410.0'

LOGGED BY: Iain F. Jenkin

0.0 30.0 Casing

30.0 96.0 Quartz-Sericite Schist

light gray, flaky across core axis revealing presence of considerable quantities of sericite. Quartz eyes form about 2% of rock.

96.0 100.8 Porphyry Dyke

dark, very fine grained matrix with 50% quartz phenocrysts. Contacts are sharp at 80° to c.a.

100.8 137.0 Quartz-Amphibole Schist

contains about 25% amphibole. Schistosity at 70°-75° to c.a.

137.0 146.5 Impure Sericite

gray; contains minor sericite and chlorite.

146.5 160.4 Porphyritic Quartz-Sericite Chlorite Schist

possibly a continuation or phase of the preceding schist. The rock contains 5-10% quartz eyes.

160.4 182.5 Quartz-Sericite Schist

gray; contains very minor chlorite. Schistosity at 80° to c.a.

182.5 280.0 Porphyritic Amphibole Gneiss

medium to coarse grained; may contain fine biotite. Quartz eyes or phenocrysts up to 1/8 in. are common. A few, short sections of quartz-sericite schist are present.

280.0 296.0 Quartz-Sericite Schist

as for 160.4-182.5 but containing more chlorite 290 - 295 highly chloritized.

- 296.0 301.0 Dark Grey Quartzite
gray; containing minor corundum and some graphite
- 301.0 353.3 Quartz-Amphibole Schist
contains up to 90% amphibole, and minor feldspar
312.5- 314.0 high feldspar content
333.3- 333.6 quartz vein
301.0- 353.3 coarse grained; trace cpy. Schistosity at
85° to c.a.
- 353.3 360.1 Quartz-Biotite Schist
- 360.1 364.4 Quartz-Amphibole Schist
- 364.4 370.0 Quartz-Feldspar-Amphibole Gneiss
The three minerals exist in approximately equal quantities.
The feldspar is brick red. The rock is not a truly gneiss,
but it is not intrusive.
- 370.0 431.0 Amphibole Schist
light-spruce green in colour due to presence of fine
epidote forming 5-10% of rock.
Some very short porphyroblasts (quartz eyes) sections.
Schistosity at 85°-90° to core axis.
337.6-391.5 porphyroblasts (quartz) Amphibole Gneiss
- 431.0 433.0 Core lens
- 433.0 413.0 Quartz-Biotite Schist
dark gray with minor green basis; epidote and chlorite are
present in very minor quantities.
Schistosity at 80° to c.a.
- 410.0 End of Hole

PROPERTY: George Lake Silica

BLK No. : 4

LOCATION: Block "A"

AZIMUTH: 115°

Lat.: 72-00N

Dip: 40°

Dep.: 7-40M

DATE: Oct.- Nov 1968

FINAL DEPTH: 183.0 M

LOGGED BY: Iain F. Dowie

0.0 43.9 Basins

43.9 49.5 Sericitic

cream/gray, contains sparse disseminated pyrite. Rusty fracturing is fairly common.

49.5 63.0 Imure Quartzite

gray quartzite, sericitic quartzite and quartz-sericitic schist.

schistosity at 70° to s.e.

55.0- 57.0 core lost

63.0- 65.0 core lost

65.0 73.1 Quartz-amphibole Schist

ground core: gray-green in colour containing much quartz and some amphibole. The entire section consists of grindings.

73.1 82.2 Graphitic Schist

again consists entirely of grindings and mud.

73.1 -77.5 charcoal gray mud-probably containing much graphite

77.5-82.2 chips of quartz & graphite; minor pyrite.

82.0 82.5 Core lost

82.5 102.2 Imure quartzite

82.5-82.6 pyrite

82.6-92.5 gray quartzite containing several, very short sections of white quartzite

92.5- 102.2 gray quartzite, weakly sericitic.

102.2 107.3 Core lost

PROPERTY: George Lake Silica

HAZ No.: 9

LOCATION: Block "A"
Lat.: 72°00N
Long.: 7°43W

AZIMUTH:
Dip: 90°

DATE: Nov. 1968

FINAL DEPTH: 75 ft.

LOGGED BY: Iain F. Dennis

0.0 25.0 Casing

25.0 42.6 Dunsmuir Sericite

gray in colour due possibly to presence of micaceous minerals. Pyrite crystals are not uncommon. There is considerable rusty fracturing at 20° - 25° to e.e.

42.6 62.6 Kaolinized Sericite Schist

less than 5 ft of core and grindings recovered. Core is partially a friable rusty sericite schist - about 18 in. high in the hole.

The remaining material recovered has the colour, and almost the consistency of putty & indicating the presence of Kaolin and/ or other clay minerals. Possibly a fault zone.

62.6 72.6 Serite-Sericite Schist

gray, showing little schistosity
62.6-68.9 2.4' of core recovered

72.6 75.0 Quartzite

rusty, highly fractured; schistosity at 15° to e.e.

75.0 End of Hole

107.3 151.6 Dark gneiss

much darker than preceding section.
110.0- 112.6 core lost
112.6- 123.6 weakly crystalline; not schistose; exhibits
consistent fracturing at 70°-75° to s.e.
123.6-128.5 core lost
128.5-150.0 containing more crystalline, but still not
schistose; massive
150.0-151.0 core lost

151.6 153.6 Pyrite zone

ground core composed of 3 parts pyrite and 1 part quartz

153.6 157.3 Chlorite Schist

contains minor pyrite, and a red mineral which may be
garnet.
154.3-155.3 core lost

157.3 171.7 Dark gneiss

dark gray becoming progressively lighter down hole.

171.7 179.5 Dark-Chlorite Schist

contains up to 40% chlorite and minor pyrite. Schistosity
at 70° to s.e.

179.5 185.0 Amphibole-Micrite Gneiss

very coarse appearance due to individual minerals occurring
in "islets"; minor chlorite is recognizable. Not truly
gneissic; may be an altered basic intrusive.

185.0 End of Hole

STATEMENT OF EXPENSES - GEORGE LAKE SILICA

Assaying & Metallurgy.....	1,076.46
Diamond Drilling.....	6,802.49
Drafting.....	925.64
Geophysical Surveying.....	2,044.61
Geology.....	1,475.76
Maps, Prints, Report, etc.....	876.38
Supervision.....	668.00
Travel Expenses.....	3,781.68
Line Cutting.....	1,632.81
<u>Total Expenditures.....</u>	<u>\$19,283.83</u>

YARMOUTH SILICA DEPOSIT
of General Silica Ltd.

The Silica deposit controlled by General Silica Ltd. in Yarmouth Co. at the south western extremity of Nova Scotia is possibly unique in the world of industrial mineral deposits to-day. Such is the case because of a coincidental combination of natural factors that has occurred in the case of this property.

These factors are listed in the following discussion which constitutes an economic appraisal of the property and deposit.

HIGH VOLUME LOW COST RAW MATERIALS

It is a generally accepted and well known fact that silica for high volume industrial uses must of necessity be a low cost commodity. To gain low costs in the production of a raw material many favorable natural factors must exist; in the case of the Yarmouth deposit these factors are present or are strongly indicated to be present.

LOCATION: This property extends from the Atlantic Ocean inland for an estimated 11 miles along a major regional geological structure. It outcrops on the beach and any operation designed to exploit the property will of course make use of this condition. In fact there is a very real possibility of being able to start an open pit just far enough inland to permit the

installation of processing, stockpiling and loading facilities and use of a straight line layout from this open pit to the boat.

In general content the property is probably the closest undeveloped high grade silica deposit to the largest market in the world i.e. the Northeastern New England states.

TONNAGE: At the present time it can only be inferred that major tonnages occur along this 11 mile strike length. The general geology is highly favorable and indicates this strongly. This opinion is shared by all who have looked at the area. Please see Dr. Behie's report on the geology. Only limited diamond drilling has been carried out up to the present time, this by the Department of Mines, Province of Nova Scotia. This drilling proved the existence of the quartzite formation at several points along the strike length. Considerable more diamond drilling is now planned to outline tonnage of ore starting near the coast.

Reconnaissance magnetometric work carried out recently (early winter) indicated the existence of a very strong zone in the two areas investigated, (one just inland from the coast and the other 11 miles away just south of Lake George). Widths of 450' were indicated near the coast not allowing for the magnetic effect of a relatively speaking, highly magnetic wall rock of amphibole schist. This type of wall rock on the east contact makes it possible to follow the zone quite easily with a magnetometer. Overburden conditions are not known definitely but estimates locally range from a few feet to 25 - 30. The magnetometer line that was run south of Lake George indicated a width of approximately 150' not allowing for wall rock affect, which in this case could be quite large as it was highly magnetic along this end of

the zone (north end).

A magnetometer survey will be run to outline the entire deposit, starting at the coast. This is to be immediately followed by diamond drilling to prove enough tonnage for optimum sized operation which would be open pit.

GRADE: In its natural state the ore is not direct shipping for white glass manufacturing. It should be direct shipping for metallurgical flux usage. Large tonnages of silica are consumed by the metallurgical industries in or near the Atlantic coast region of the U. S. industrial northeast. On the wider D.D. intersection (W. S. Government drilling programme) the average SiO_2 grade runs over 98% approximately 98.5% with consistent and low magnesia sodium (as Na_2O) and iron. However the iron, which occurs as scattered small aggregations of sulphides (some enloopyrite was noticed). These sulphides do not or are not an integral part of the quartz grains based on initial metallurgical results, and a preliminary opinion by a major mining laboratory is that glass grade sand can be produced from this ore.

Although referred to as a quartzite this material is closer to a sandstone with very even grain size. It would mineralogically possibly be more correct to call this particular rock a recemented sandstone. This is of notable importance as it means drilling, blasting (if required) and grinding costs should be relatively low. Initial laboratory sized grinding tests indicate this to be true and the ore breaks down easily into an even grained silica sand. This evenness in grain size is another factor that is important to glass manufacturers as it makes it relatively easy for them to control their melt and thus lead to economics in production.

OTHER FACTORS: Fresh water, labour and power are available in the immediate area. There would be no need to build a town site or long power lines into the mining area. Roads are abundant along the deposit.

CLIMATE: The climate in this area is highly favorable compared to any other part of Canada except British Columbia. Winter temperatures rarely drop to zero, in fact they usually range between 18° to 35° F. throughout the winter months. Snow accumulation is low.

DOCK FACILITIES: There are no dock facilities in the immediate area, i.e. at the coast but there are facilities in Yarmouth, an average of 10 miles distance from the deposit. The development of major tonnages of high grade silica here would warrant the construction of loading facilities at the site as pointed out earlier in the report.

ASSOCIATED POSSIBILITIES: Two major possibilities will evolve along with the development of this property to supply high grade silica sand and other silica products for the export and Canadian market. These are the building of an intermediate size glass manufacturing facility at or near the open pit to supply the Maritime market area and the possibility of building another silica consuming plant. This means that proving and developing a major silica mine in this location could lead to the establishment of several secondary industries at or near the site.

CONCLUSION: As an industrial mineral prospect located for supplying an international market this property warrants a complete exploration programme of major proportions. The work already done supports such a recommendation and the overall strategic location of the property makes it a difficult one to overlook. The above outlined factors when combined support the desirability of a development programme. It could be said that they indicate this property

to be rather unique as a potential silica producer.

J. E. M. Dave
January 7, 1968
(In flight Winnipeg to
Vancouver)

(10)
COPY

DOMINION STEEL & COAL CORPORATION LTD
SYDNEY, N.S.

C
O
P
Y

Laboratory, March 29th, 1945.

Mr. W. S. Wilson
Chief Engineer.

Dear Sir: Silica Rock From Yarmouth County, N.S.

The sample of silica rock forwarded by Dr. Cameron (Deputy Minister of Mines) and referred to in your letter of March 21st. was duly received. The sample was of about 160 lb. weight and consisted of lumps of about 1/2" size with no fines or oversize. We selected by quartering down a portion for analysis which showed the following:-

Loss on Ignition	0.12
Silica	98.98
Ferric Oxide	0.13
Aluminum Oxide	0.42
Lime	0.20
Magnesia	0.02
Undetermined	0.13

This is a very good rock chemically and we noted that in crushing it it seemed to give a splintery type of particle which is supposed to be desirable for brick manufacture. The remainder of the sample (about three-quarters of the total) we are putting through our jaw crusher here to crush it as fine as practical and Mr. Tomblin will take this crushed material for the manufacture of a few trial brick.

Yours very truly,
(sgd.) I. C. Mackie
Engineer of Tests.

431245

41 - B-01(00)

RE SILICA AT CHEGOGGIN
POINT, YARMOUTH CO.

FROM DEPUTY INSPECTOR OF MINES
TO INSPECTOR OF MINES

On March 1st I visited the quartz exposure on the beach near Chegoggin Point, Yarmouth Co. A sample of approximately 150 lbs. was taken from this showing and a further 50 lbs. from the quartz float in the adjacent fields. At the Nova Scotia Technical College these samples were crushed to $\frac{1}{4}$ " and three 5 lb. portions taken for analysis at the Technical College.

The small samples were (a) discoloured quartz representing an average product; (b) white quartz from the beach exposure; and (c) the quartz float. The rejects were combined and shipped to the Nova Scotia Steel Company at Sydney for bulk testing.

H. N. Curry
m.s.g.

March 10, 1945

12

COPY

W.L.

DOMINION STEEL & COAL CORPORATION LTD

SYDNEY

Engineering Department
April 4th, 1945.

Dr. Alan E. Cameron
Deputy Minister of Mines
Province of Nova Scotia
Halifax, N. S.

Dear Dr. Cameron: Re: Silice Rock From Yarmouth County, N.S.

The sample of Silice Rock which you sent us from Yarmouth County has been analysed and we attach copy of our Mr. I. C. Mackie's report of March 29th, 1945, hereto.

The analysis of this rock is excellent and the structure is promising. It would be a wonderful thing if we could find rock like this in Cape Breton or at least where the transportation charges would not be so high.

I will let you know how the sample brick turn out.

Thanking you for your interest and with best regards.

Yours truly,

Sgd. W. S. Wilson
CHIEF ENGINEER

WSW/SF
c.c. Mr. A. E. Flynn
Prof. of Mining Engineering
Nova Scotia Technical College.

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RE SILICA AT CHEOOGGIN POINT
YARMOUTH COUNTY

FROM DEPUTY INSPECTOR OF MINES
TO INSPECTOR OF MINES

On May 9th our portable compressor was placed on the property of S. MacKinnon, Pembroke Shore, Yarmouth County, and mining operations commenced on an outcrop of quartzite. This outcrop was located on the strike of the belt approximately 1500 feet inland from the beach exposure previously sampled.

Of the rock broken approximately 50 tons was trucked to Yarmouth and loaded in a hopper type car. On May 21st this car was billed out freight collect over C. N. R. lines to the Dominion Steel & Coal Company, Sydney, N. S.

The rock in this shipment was a bit more discoloured than that in the previous small sample but was representative of a run of quarry product.

H. N. Curry

May 29, 1948

Analyses by Dominion Steel & Coal Co. Ltd.

Sample shipment May 1945

Carload shipment May 1945

Loss on Ignition	0.12
Silica	98.78
Iron Oxide	0.13
Aluminum Oxide	0.42
Lime	0.20
Magnesia	0.02
Undetermined	0.13

Sample

C
O
P
Y

DOSCO

Sydney
Nova Scotia

Engineering Department,
November 23rd, 1945.

Mr. J. P. Messervey,
Acting Deputy Minister,
Department of Mines,
Halifax, N. S.

Re: Chegoggin Point Silica Rock.
Your File 21-1-4

Dear Sir:-

We are in receipt of your letter of the 22nd.
requesting the analysis of the shipment forwarded us.

This shipment was received by us on June 1st,
1945 in car D & H 11209.

Our laboratory furnished the following analysis:-

Ignition Loss	- 0.12
Silica	98.98
Ferric Oxide	0.13
Alumina	0.42
Lime	0.20
Magnesia	0.02
Undetermined	0.13

Trusting this information is satisfactory, we are,

Very truly yours,

"WILLIAM L. STUBBS"

VLS/SY

15

Report No. 410

THE PREPARATION OF SILICA SAND FROM THE RIVER DENYS SAND AND CLAY CO., LTD., MELFORD, CAPE BRETON, N.S.

R. K. Carnochan

Shipment. Three bags of sand were received on September 25, 1930, from the River Denys Sand and Clay Co., Melford, Inverness county, Cape Breton, N.S. The shipment consisted of one bag of coarse sand, 92 pounds net weight, and two bags of fine sand, 168.5 pounds net weight.

Purpose of Experimental Tests. Tests were desired on both the coarse and fine sand to determine if sand suitable for making clear glass or for sand-blasting could be prepared from them.

Characteristics of the Sand. Both lots of sand were sharp and contained quite an amount of light-coloured clay, and a little white mica. The coarse sand ranged in size from about 6 mesh down and the fine from about 10 mesh.

Sampling and Analysis. A head sample was cut out of each lot by means of a Jones riffle having slots 1 inch wide. In cutting the fine sand a piece of rusty agglomerated sand and a piece of rock would not pass through the 1-inch slots. These weighed 126.3 grammes or 0.28 pound. They were kept separate and called +1 inch from fine sand.

Analysis gave:

	Fe ₂ O ₃ per cent	Per cent of heads
Head sample coarse sand.....	0.31	100.0
Sample fine sand - 1 inch.....	0.19	99.83
+ 1 inch from fine sand.....	15.49	0.17

EXPERIMENTAL TESTS

The test work was divided into two parts, the first being preparation of glass sand and the second, preparation of blast sand.

Preparation of Glass Sand

Four different methods were tried for the preparation of glass sand. These were washing; washing and magnetic separation; washing and tabling; and washing, tabling and magnetic separation.

Washing. Small samples of the coarse and fine sand were agitated for 1 hour in a revolving porcelain jar. The jar contents were washed by decantation from a pail three times. The washed sand and decanted sand and clay were dried. Screen tests were made on cut samples of the washed sands from each lot.

Product	Coarse lot			Fine lot		
	Grms.	Per cent of heads	Fe ₂ O ₃ per cent	Grms.	Per cent of heads	Fe ₂ O ₃ per cent
Feed	1,140.2	100.0	0.31	1,137.9	99.84	0.19
Washed sand	1,062.0	93.14	0.13	961.5	87.25	0.11
Decanted sand and clay	74.0	6.49	1.27	136.7	11.99	0.40

Screen Tests on Washed Sands

Size	Coarse lot			Fine lot		
	Weight, per cent	Per cent of heads	Fe ₂ O ₃ per cent	Weight, per cent	Per cent of heads	Fe ₂ O ₃ per cent
+ 20.....	10.61	9.48	1.43	2.04	1.78	2.42
- 20+ 28.....	10.90	10.15	0.076	3.99	3.48	0.12
- 28+ 35.....	44.88	41.80	0.070	25.69	22.42	0.040
- 35+ 48.....	21.20	19.73	0.086	38.00	31.41	0.034
- 48+ 65.....	7.96	7.41	0.16	20.99	18.31	0.074
- 65+ 100.....	2.93	2.78	0.21	7.90	6.89	0.17
- 100.....	1.17	1.37	1.43	3.39	2.96	1.14
	100.00	93.14	0.250	100.00	87.25	0.144

Sand for making clear glass should not contain over 0.06 per cent Fe₂O₃ plus TiO₂. Only two of the sizes in the screen tests were 0.06 per cent or less Fe₂O₃ alone without considering TiO₂. These sizes were -28 + 35 and -35 + 48 in the washed sand from the fine lot. These sizes were not run for TiO₂ because the washing, tabling, and magnetic separation tests on the fine lot gave more than 0.06 per cent Fe₂O₃ plus TiO₂ in both these sizes. Hence it was concluded that in a test using washing only these two sizes would be over the required limit.

Washing alone will not give any products suitable for making clear glass.

Washing and Magnetic Separation. Cut samples of the washed sand of each lot were run over an Ullrich magnetic separator using a current of 10 amperes. The Ullrich removes tourmaline, magnetite, grains of quartz with tourmaline attached, flakes of white mica with tourmaline embedded in them, and also a very small amount of other minerals amongst which is garnet. In the non-magnetic are very fine grains of tourmaline both free and attached, discoloured quartz grains, and white mica. Screen tests were made on the non-magnetic from each lot.

Product	Coarse lot		Fine lot	
	Grms.	Per cent of heads	Grms.	Per cent of heads
Ullrich non-magnetic.....	474.3	92.90	462.4	86.84
Ullrich magnetic.....	1.2	0.24	2.2	0.41

Screen Test on High Non-Magnetic

Size	Coarse lot				Fine lot	
	Weight, per cent	Per cent of heads	Fe ₂ O ₃ , per cent	TiO ₂ , per cent	Weight, per cent	Per cent of heads
+ 8	1.26	1.17				
- 8 + 10	1.46	1.36				
- 10 + 14	2.99	2.45				
- 14 + 20	5.46	4.49			0.81	0.70
- 20 + 28	10.58	9.83	0.038	0.014	0.97	0.84
- 28 + 35	44.35	41.20	0.029	0.015	3.74	3.25
- 35 + 48	22.72	20.12			21.52	20.25
- 48 + 65	7.91	7.35			25.74	24.04
- 65 + 100	3.03	2.84			24.96	18.49
- 100	1.41	1.34			10.44	9.07
	100.00	92.90			3.69	3.20
					100.00	86.84

Only the two sizes -20 + 28 and -28 + 35 from the coarse lot were analysed for Fe₂O₃ and TiO₂ as the washing, tabling and magnetic separation test showed only these two sizes below the required limit, and it was concluded that any size over the limit in the washing, tabling and magnetic separation tests would be over the limit in a washing and magnetic separation test.

The two sizes -20 + 28 and -28 + 35 from the coarse lot could be used to make clear glass. Together they represent 54.03 per cent of the coarse lot.

Washing and Tabling. A small cut sample of each lot of sand was agitated for one hour in a revolving porcelain jar and was then washed three times by stirring in a pail, letting the pail contents stand for one minute and decanting.

The washed sand was then dried and run over a small Willey table making two products. The product reporting higher up on the table was called table concentrates and consisted mostly of sand. In these table concentrates were some large grains of quartz, rock and rusty agglomerated sand as well as some tourmaline and a small amount of magnetite. The product reporting lower down was called tabled sand and contained no large grains, a small amount of fine tourmaline and magnetite and some white mica. Screen tests were made on the tabled sands from each lot.

Product	Coarse lot				Fine lot		
	Grams	Per cent of heads	Fe ₂ O ₃ , per cent	TiO ₂ , per cent	Grams	Per cent of heads	Fe ₂ O ₃ , per cent
Feed.....	1,290.7	100.00	0.31		1,175.4	99.83	0.19
Washed sand.....	1,215.3	94.31			1,056.7	89.75	
Table concentrate.....	86.5	6.70	1.00		93.6	7.95	0.85
Tabled sand.....	1,125.7	87.22	0.02	0.032	959.2	81.47	0.076

Screen Tests on Filled Sands

Size	Coarse lot				Fine lot			
	Weight, per cent of heads	Weight, per cent of heads	Fe ₂ O ₃ , per cent	TiO ₂ , per cent	Weight, per cent of heads	Weight, per cent of heads	Fe ₂ O ₃ , per cent	TiO ₂ , per cent
+ 10	1.11	0.8	0.04	.....	0.29	0.24	1.15	.....
- 10 + 14	2.19	2.17	0.08	.....	1.25	1.02	0.25	.....
- 14 + 20	5.75	4.71	0.064	0.019	4.48	1.67	0.08	.....
- 20 + 28	11.50	11.77	0.039	0.024	4.48	21.09	0.048	0.021
- 28 + 35	47.73	41.65	0.032	0.024	2.29	30.56	0.018	0.025
- 35 + 48	19.56	16.09	0.042	0.029	7.71	11.97	0.062	0.015
- 48 + 65	9.21	3.42	0.08	.....	18.67	5.00	0.09	.....
- 65 + 100	2.12	1.85	0.14	.....	3.70	3.01	0.07	.....
- 100	2.02	1.77	0.45	.....	.....	.....	.....	.....
	100.00	87.22	0.075	.....	100.00	81.47	0.073	.....

Only the one size, - 28 + 35 from the coarse lot, is low enough in iron and titanium to allow it to be used for making clear glass. This size represents 11.66 per cent of the coarse lot.

Washing, Tabling and Magnetic Separation. Cut samples of the tabled sand from each lot were run over an Ullrich magnetic separator using a very strong current, 10 amperes. The separation secured was similar to that described under washing and magnetic separation. Screen tests were made on the non-magnetic from each lot.

Product	Coarse lot			Fine lot		
	Grams	Per cent of heads	Fe ₂ O ₃ , per cent	Grams	Per cent of heads	Fe ₂ O ₃ , per cent
Feed	75.7	87.22	0.072	482.2	81.47	0.076
Ullrich non-magnetic	75.7	87.06	0.065	482.2	81.30	0.08
Ullrich magnetic	0.5	0.08	13.80	0.5	0.08	14.25

Screen Tests on Ullrich Non-Magnetic

Size	Coarse lot				Fine lot			
	Weight, per cent of heads	Per cent	Fe ₂ O ₃ , per cent	TiO ₂ , per cent	Weight, per cent of heads	Per cent	Fe ₂ O ₃ , per cent	TiO ₂ , per cent
+ 10	1.43	1.24	0.13	.....	0.45	0.37	1.14	.....
- 10 + 14	2.51	2.15	0.065	.....	1.22	0.99	0.18	.....
- 14 + 20	5.75	5.01	0.049	0.013	5.42	4.41	0.08	.....
- 20 + 28	14.09	12.27	0.040	0.013	32.92	26.76	0.037	0.020
- 28 + 35	49.08	43.51	0.037	0.015	23.47	27.21	0.037	0.025
- 35 + 48	16.78	14.61	0.049	0.022	16.57	13.47	0.07	.....
- 48 + 65	3.42	4.72	0.069	.....	6.24	5.07	0.10	.....
- 65 + 100	2.00	1.74	0.12	.....	3.71	3.02	0.29	.....
- 100	2.04	1.75	0.32	.....	.....	.....	.....	.....
	100.00	87.06	0.051	.....	100.00	81.30	0.078	.....

Only two sizes of the coarse lot are low enough in iron and titanium to allow them to be used for making clear glass. These sizes are the $-20 + 28$ and the $-28 + 35$ and together they represent 55.78 per cent of the heads.

SUMMARY OF TESTS FOR THE PREPARATION OF GLASS SAND

It will be noticed that the analyses of some of the products that were screened have been calculated from the analyses of the screened sizes, and that the analyses obtained in this way do not always check closely the analyses obtained from the products before screening. Also, if the analysis of a separated product is calculated from the analyses of the products into which it was separated the value obtained does not always approximate the value obtained by direct analysis. Moreover, if the analyses of the prepared sizes are compared, small errors are revealed by the fact that some sizes give lower iron values by washing and magnetic treatment or by washing and tabling than by washing, tabling and magnetic treatment, and also that some sizes in the fine lot give lower iron values by washing than by washing and tabling and washing, tabling and magnetic separation.

However, the results have been put down just as obtained and it is believed that they are sufficiently correct for the purpose intended, besides this method will give a good idea of the accuracy of the work.

No sand suitable for making clear glass was obtained from the fine lot. The following table gives the percentage of sand suitable for making clear glass obtained by the different methods of treatment from the coarse lot,—

Method of Treatment	Glass sand recovered, per cent
Washing.....	0.00
Washing and magnetic treatment.....	51.03
Washing and tabling.....	41.46
Washing, tabling and magnetic treatment.....	55.78

Considering that magnetic treatment by means of a high power machine, similar to the one used in the tests, is expensive and that glass sand is a cheap commodity, it would seem advisable to remove deleterious material by simply washing and tabling the coarse sand. The recovery by this method would be 41.46 per cent.

Preparation of Blast Sand

The remaining sand of the coarse lot and the remaining -1 -inch sand of the fine lot were each washed four times by means of an Akins classifier. The four washes in the Akins would be equivalent to the treatment usually given when washing a sand. The washed sands were dried and screened on a 20-mesh Hummer screen. The following table gives the results of this work,—

Product	Coarse lot		Fine lot	
	Pounds	Per cent of heads	Pounds	Per cent of heads
Sand before washing.....	88	100.00	100	99.83
Sand after washing.....	81	92.05	140	87.35
+20 mesh.....	14	15.91	7	4.37
-20 mesh.....	67	76.14	133	82.98

A screen test was made on each of the -20-mesh products with the following results, —

Screen size, mesh	Coarse lot, per cent	Fine lot, per cent
+ 20	0.10	0.02
- 20+ 28	10.42	2.27
- 28+ 35	51.21	29.72
- 35+ 44	24.44	37.84
- 44+ 65	9.00	19.65
- 65+ 100	4.28	8.12
- 100	1.55	2.42
	100.00	100.00

Sixty-five pounds of the -20 from the coarse lot and 100 pounds of the -20 from the fine lot were shipped to the C.P.R. at Montreal, where they were used in tests with a regular sandblast outfit in the Angus shops.

Besides testing the River Denys sand the C.P.R. tested several other Canadian sands and an imported sand. The results of these tests have been published by the Mines Branch in Report No. 727-1, entitled "The Suitability of Certain Canadian Sands for Use in Sandblasting."

The sandblasting test showed that both the lots of River Denys sand that were tried were good blast sand.

CONCLUSIONS

1. No glass sand suitable for making clear glass can be obtained from the fine lot.
2. By washing, tabling and screening 41.46 per cent of the coarse lot can be recovered as sand suitable for making clear glass.
3. By washing and screening 76.14 per cent of the coarse lot and 82.98 per cent of the fine lot can be recovered as good blast sand.

Report No. 411

THE TESTING OF SILICA SAND FROM GUIGUES TOWNSHIP, TÉMISCAMINGUE COUNTY, QUEBEC, FOR SANDBLASTING

R. K. Carnochan

Shipment. A carload of silica sand, shipping weight 47,100 pounds, was received on October 11, 1930. The carload had been sent in by the Development Department of Canadian Pacific Railway, Montreal. The sand came from a property in Guigues township, Témiscamingue county, Quebec, on the east side of lake Timiskaming.

Purpose of Experimental Tests. The C.P.R. desired that the sand be prepared and samples sent to them to try out in a regular sandblasting outfit at their Angus shops in Montreal in comparative tests with an imported sand and other Canadian sands.

QUARTZ SAND AND CLAY DEPOSITS, MELFORD, CAPE BRETON

By T. D. Guernsey

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INTRODUCTION

The writer made, during the summer of 1926, an investigation of a deposit of quartz sand and clay which occurs near River Denys station, Cape Breton. This investigation was carried out in conjunction with the geologic mapping of an independent area to the south.

The writer desires to acknowledge the kindness and courtesy shown by the officials and employees of the River Denys Sand and Clay Company, owners of the deposit; to Mr. J. A. MacLellan and Mr. D. J. Beaton, manager and foreman respectively, he is especially indebted. M. E. Wilson of the Geological Survey visited the writer in the field and his suggestions and criticisms were very much appreciated. Special thanks are due to the School of Mines, Columbia University, for the use of apparatus in making screen tests. To Professor C. P. Berkey, Professor Ida M. Ogilvie, and Mr. H. P. Woodward, of the Department of Geology, Columbia University, the writer is indebted for criticisms and suggestions during the preparation of the report. Mr. R. M. Williams of Halifax proved to be a very willing and capable assistant.

The deposit is located on Diogenes brook, Inverness county, Cape Breton. The workings are about 4 miles from the village of Melford, and about 10 miles from River Denys station of the Intercolonial Division, Canadian National railway. The deposit is owned and operated by the River Denys Sand and Clay Company, Limited, whose headquarters are at Melford; Mr. J. A. MacLellan is president and managing director. The chief product is moulding sand, which is shipped to Sydney, Cape Breton, and to New Glasgow, Nova Scotia. A little clay has been shipped to St. John, New Brunswick, for use in the manufacture of pottery.

Although the deposit was known for nearly forty years, and some work had been done prior to 1911, it was not exploited to any extent until 1917, when it was acquired by the present owners. The property from

which the sand is mined consists of 95 acres and, in addition, the owners hold leases and rights of search over a greater area in the vicinity.

Owing to the location of the property it was necessary to rebuild and construct nearly 4 miles of road in order that material might be brought to, and sand taken from, the deposit. This road, completed in 1924, connects with Victoria highway near Melford, from whence a branch road leads to the railway near River Denys station. Active mining commenced in 1924.

So far as the writer knows, the only published information on sand in this district is to be found in the report of H. Ries and J. Keele on "The Clay and Shale Deposits of Nova Scotia and Portions of New Brunswick".¹ Mr. Keele, who visited the locality, reported as follows:

A deposit of white clay is found near the headwaters of Diogenes brook, one of the tributaries of Denys river. This brook cuts through the eastern flanks of the Craignish hills, which form the western border of a wide valley across which Denys river flows.

The clay is at present only exposed at one point on the brook at a short distance below a small fork that comes in from the west. A few years ago a small quantity of the clay was shipped, but the openings made then are now concealed by gravel slides.

The portion of the brook where the clay occurs is situated in a narrow gorge of steep grade, sunk to a depth of about 250 feet below the level of the upland. A road was built down the brook leading to the open valley below, in order to haul the clay to River Denys station, a distance of 9 miles. The bottom of the gorge is so narrow that there is scarcely room for both the road and the brook.

Borings made in the clay were said to have revealed a sufficient thickness to form a workable deposit, but that the clay was interstratified by sandy layers. The deposit, however, appears to be of limited width, as rim rock outcrops at several points along the gorge. Any attempt to mine the clay on a large scale is liable to serious interruption by land slides from the glacial drift, which clings in large masses to the steep slopes.

Both the valley bottom and the slopes of the gorge are now heavily timbered, which serves to hold the loose material in place.

At the forks of the stream, at the upper end of the clay deposit, is a considerable thickness of white, clayey sand, from which the white clay appears to have been derived by the washing of the brook. The white sand appears to be preglacial and is probably derived from the igneous rocks which form the upland. The principal rocks are felsite, syenite, and sericite schist, judging by the wash in the brook.

A short distance below the white sand a mottled red and dark blue clay is found widespread in the valley through which Denys river meanders, and is worked for brickmaking at Eden siding on the Intercolonial railway. This clay overlies the glacial drift in the valley, and may be a lake or estuarine clay. If so it would indicate a greater submergence for the land than has been indicated for this region.²

GENERAL GEOLOGY

Diogenes brook flows down the southern slope of an upland area known as the Craignish hills, which trend east-of-north from the strait of Canso. They are about 4 miles wide and their extreme summits are about 980 feet above sea-level. The general appearance is that of a rather flat-topped ridge, rising abruptly from broad, lowland areas and incised by numerous swift-flowing streams, all of which rise in the highland.

¹Geol. Surv., Canada, Mem. 16, pp. 155 (1911).
²Op. cit., pp. 65-66.

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It is probable that all the carbonate rocks of the George River series are more or less magnesian. Variations occur in the colours, textures, and structures, and these were used to make a rough division between what are probably true dolomites and the magnesian limestone. The dolomite is best seen along the road, about halfway between the sand deposit and the mouth of the valley, where it is exposed in small cliffs. In colour it is buff, grey, or reddish, with the buff-coloured varieties predominating. Mixtures of these three colours are common. The texture as a rule is fine, although the coarse sugary texture, common to dolomites, is very marked in some places. Bedding or banding is lacking, and no clue was obtained which might throw light on the original structures. The fine-textured varieties are commonly brecciated, presenting, on both the weathered and freshly broken surfaces, a network of anastomosing veinlets of clear or reddish carbonate. In places the rock appears to have been replaced, but if this is so the evidence is very obscure. Banded limestones are exposed on the valley side north of the sand deposit. They appear to carry less magnesium than the buff-coloured rocks, and in colour are white or grey, with medium texture. Well-defined banding is especially prominent on the weathered surface, which assumes a blue-grey colour.

The George River quartzites seen along the valley sides, both above and below the sand deposit, as a rule are massive rocks with few structures. They are white or light grey on the weathered surface, but when freshly broken are pinkish, due to ferric oxide between the grains, which dissolves out on weathering to form small pits. The strike of the largest exposure is 75 degrees (magnetic). Magnetite occurs on the south side of the valley not far from the mouth. The magnetite is in bands up to an inch or more in thickness and is associated with quartzite and sulphides, in a zone about 5 feet wide. The rocks in the vicinity are somewhat darker than the other exposures of quartzite observed, and display considerable shearing. A drift about 40 feet long, carried in along this zone during the summer of 1926, showed many small faults. At the time of the writer's visit the magnetite zone was faulted from the drift face.

The George River schists in the vicinity of the sand deposit are dark, fine-grained rocks, usually stained with ferric oxide. Cleavage is well developed and there appears to be no limit to which the rock will not cleave. This feature makes unweathered surfaces of rather rare occurrence. The schists are associated with some thin, blue, limestone bands, and are cut by small melanocratic dykes.

The small exposures of Carboniferous sediments occur at the eastern edge of the area mapped. These exposures are over a mile from the mouth of the valley, where the normal Carboniferous succession begins. They include a very small exposure of coal in the bottom of the brook, and a slightly larger mass of gypsum which was uncovered by a cut made during the building of the road. No definite structures were noted in the gypsum, but the coal seam, whose width was not uncovered, apparently strikes 156 degrees (magnetic) and dips about 30 degrees west. The coal is very tender and has not entirely lost its woody character. Small plates of gypsum occur in the carbonaceous layers. This occurrence is believed to represent

The sand occurs where Diogenes brook flows in a deep valley cut into Craignish hills. The immediate relief is in the neighbourhood of 300 feet, and although the valley sides are well wooded, they are very steep and, in many places, even precipitous.

The rocks making up Craignish hills have been mapped by Fletcher¹ as Precambrian, and are by him divided into two groups: (1) a series consisting of "syenitic, gneissoid, and other feldspathic rocks"; and (2) a series called the George River Limestone. Both series have been metamorphosed and are highly crystalline. Occupying the broad, open valleys and penetrating into the crystalline area as occasional re-entrants are Carboniferous sedimentary strata. These are unconformable to the older crystalline complex, and although at the present time their chief development is in the valleys, there is little doubt that at one time they extended farther up the slopes, if not over the summits, of the present hills. In the main, the higher overlapping members have been stripped off by erosion, and their remnants are of rare occurrence. Unconsolidated deposits of fluvial, lacustrine, and glacial origin rest on both the crystalline rocks and the later sediments, although for the most part their development is limited to the valleys.

A hasty reconnaissance over the area failed to show many exposures of the granitic series, but those noted resembled very closely rocks which have been studied by the writer in a similar area about 10 miles to the south. In the southern area they are granitic rocks, of coarse grain, with large, pink or flesh-coloured feldspars, large quartz grains, and hornblende or mica, or both. The ferromagnesian minerals vary in their relative proportions over local areas, and the mica may show considerable chemical variations, being in some cases very biotitic and in others tending toward the light-coloured varieties. The granitic rocks in many outcrops hold partly digested xenoliths, whose original character is completely destroyed. Where larger portions of the intruded material are present, the rock becomes gneissoid in structure, the colour deepens, and the texture becomes finer. On exposure to the weather the granite disintegrates very rapidly by decay or solution of the feldspars, leaving the quartz grains as nobby protuberances on the surface. As weathering continues, the quartz is liberated and accumulates at the bottom of the outcrop as coarse, siliceous sand, very similar in appearance to rock salt.

According to Fletcher's map (No. 19) the valley of Diogenes brook is cut in the George River series. In its typical development this group is described as "crystalline limestone and dolomite . . . interstratified with . . . quartzite . . . and hornblende schist"² and intruded by igneous rocks. The strata are highly metamorphosed and are inclined at high angles. All the rocks common to the George River series in the type area were noted in the valley of Diogenes brook, although the true sediments have by far the largest development. The structural trend of the series is northeast (magnetic), with steep dips, and much crumpling and shearing.

¹Fletcher, H.: "Report on Part of the Counties of Richmond, Ivershem, Guyaborough, and Antigonish, Nova Scotia"; Geol. Surv., Canada, Rept. of Prog. 1874-80, pt. F, pp. 10-14, 24-32.
²Fletcher, H.: "Report of Explorations and Surveys in Cape Breton, Nova Scotia"; Geol. Surv., Canada, Rept. of Prog. 1875-76, p. 323.

a small block, down-faulted into the crystalline complex. The reason for postulating a fault is the westerly dip of the coal seam which, under normal conditions, should dip to the east at a small angle.

The glacial and other unconsolidated deposits are of variable thickness and are generally red or chocolate-coloured. They consist of gravels and sands, developed as delta deposits on the lowlands, and derived in large part from the crystalline rocks of the highlands. Many of the deposits are of flood-plain origin, and consist of fine, red gravels interstratified with red and grey clays. Glacial till is common over the whole district and consists of fragments of crystalline rocks mixed with finer siliceous and argillaceous material having the prevailing red colour.

DESCRIPTION OF THE QUARTZ SAND AND CLAY DEPOSIT

With the exception of the above-mentioned coal and gypsum at the lower end of the deposit, no exposures of bedrock were noted within the area where the quartz sand occurs. The sand is found directly beneath the unstratified and heterogeneous glacial drift, which is thinnest at the bottom of the valley and increases in thickness up the slopes. The boundaries of the deposit have not been exactly delimited, although the sand probably does not extend laterally beyond the nearest bedrock exposures.

Since the glacial drift is thinnest at the bottom of the valley, it is there that the sand is exposed with the least work and to the best advantage. The sand is exposed by six excavations, three tunnels, and a number of test pits. The locations of these and other points where the sand was observed are indicated on the accompanying map (Figure 20).

The sections exposed in the larger excavations show that the deposit is bedded. The beds range in thickness from a few inches to 3, or even 5, feet. In some, but not all, cases, alternate beds differ in texture. Clay is present in greater or less quantity in all the beds of sand and forms beds of itself.

The sand is silvery or yellow-brown and consists of quartz grains, silvery mica, and creamy white or grey clay. The quartz grains vary in size from very fine particles, almost too small to be seen with the unaided eye, to pebbles a quarter of an inch or more in diameter. The larger grains have the edges and corners well rounded. When freshly exposed the sand is rather dark and is fairly compact, but as drying proceeds the colour lightens and the mass becomes more friable. Where beds of clay occur, the colour is generally grey, and, rarely, white. The clay is gritty, indicating the presence of siliceous material.

The contact of the sand with the overlying glacial drift is sharp, and does not follow the slopes of the valley. Thus, the tunnel at test-hole No. 14 follows the contact into the hill-side where a layer of nearly white clay overlies the sand. The top of the sand at the end of the longest tunnel, west of test-hole No. 13, is said to be about 6 feet above the back, which would indicate that the depth of the glacial drift over the end of the tunnel was 35 feet. At test-hole No. 3 the contact of the sand with the drift plunges sharply westward, and as no sand is known to occur west of this

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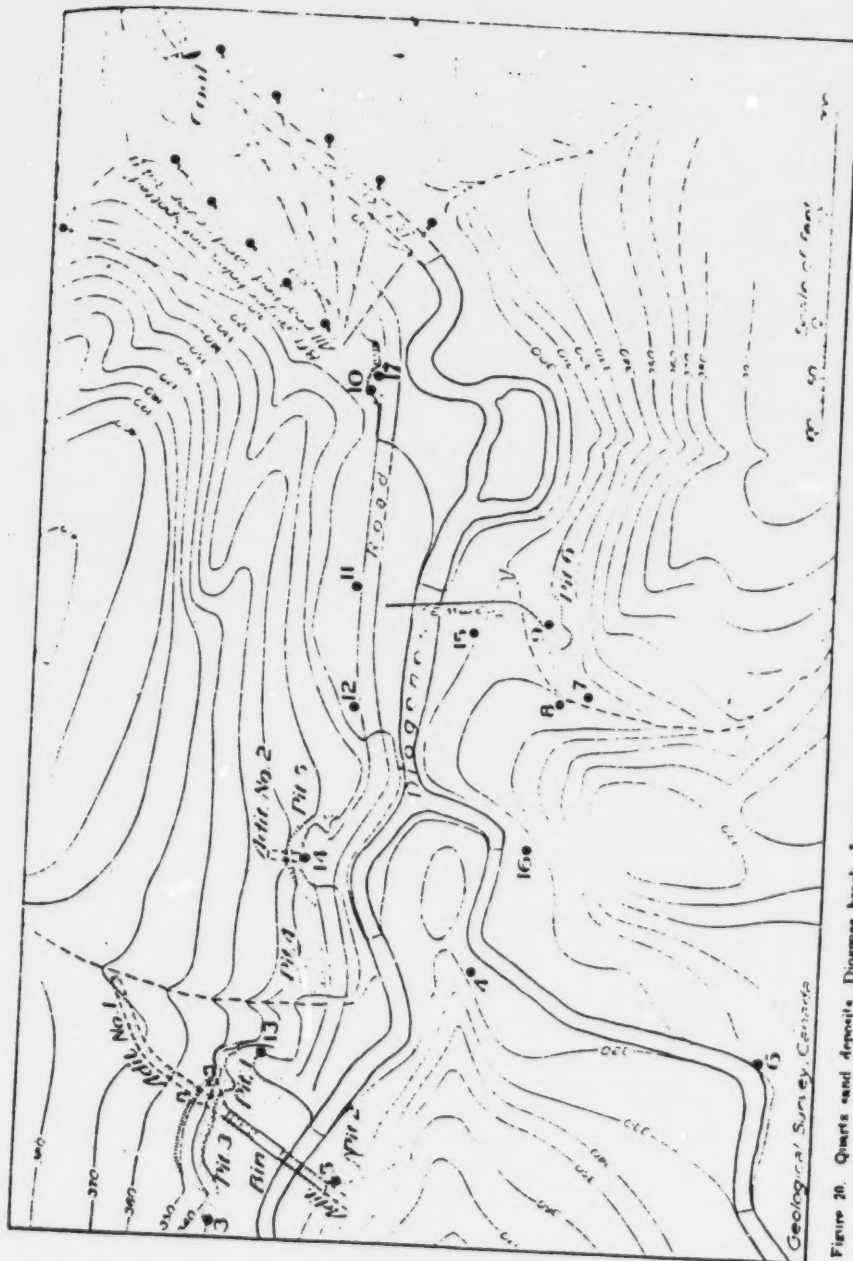


Figure 20. Quartz sand deposits, Inverness county, Nova Scotia. Exposures (mainly artificial) of sand shown by dotted pattern; text. Holes in sand by solid circles numbered as in text.

point it may be taken to indicate the western limits of the deposit. At test-hole No. 7 the contact plunges into the hill-side with a steep southerly dip.

In the larger artificial exposures where cuts were made into the deposit the beds dip at angles of about 40 degrees east, i.e. down stream. This angle exceeds the angle of repose of dry sand in air by 6 degrees and although there does not appear to be any good reason why it may not at times be exceeded, it is not believed to represent the original dip of the sand layers. Some beds, especially those in which the clay content was high, were more lenticular than others, but since the exposures were not of sufficient extent to permit a single bed to be traced any distance, the lensing did not appear prominently.

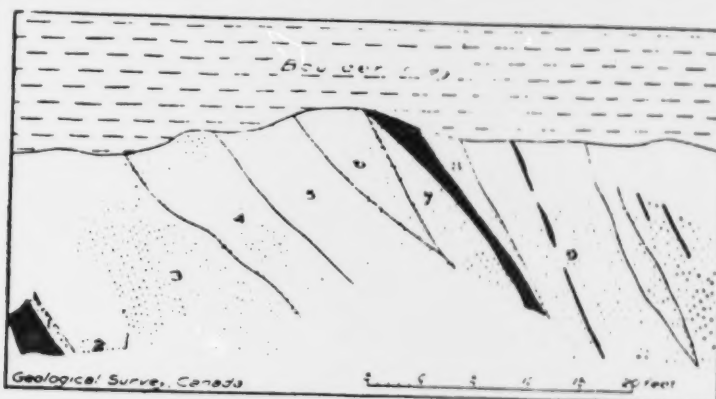


Figure 21. Sand and clay in face of large excavation near test-hole No. 13; by M. E. Wilson. Clay shown in solid black; sand by pattern of dots. Layer No. 1 is composed of pebbly sand, No. 2 of coarse sand, No. 3 of medium-grained, crossbedded sand, No. 4 of coarse sand, No. 5 of moderate fine sand, No. 6 of fine, crossbedded sand, Nos. 7 and 8 of fine, crossbedded sand containing clay, and No. 9 of fine sand containing clay beds.

The large excavation near test-hole No. 13 exposes a subsidiary series of what at first sight appear to be bedding planes (See Figure 21). These latter are steeper than the normal dips, being about 70 degrees, and intersect, but apparently do not cross, the normal structures. The dip-planes separate thin laminae of rather lenticular outline, which do not exhibit gradations in texture from one to the other. The exact significance of these structures is not clear. They may be the effects of slight slumping during or after the deposition, or on the other hand they may be the result of some outside force which has modified the deposit. Glacial ice is a common cause of deformation in unconsolidated deposits. Not only do the movement and weight of the ice play an important role, but the partial cementation of the material through freezing causes it to act in a manner which appears wholly anomalous when the ice melts.¹ Deformation structures

¹Berkey, C. P., and Hyde, J. E.: "Original Ice Structures Preserved in Unconsolidated Sands"; Jour. Geol., vol. XIX, pp. 223-231 (1911).

Hollick, A.: "Dislocations in Certain Portions of the Atlantic Coastal Plain Strata and Their Probable Causes"; N.Y. Acad. Sc. Trans., vol. XIV, pp. 8-20 (1894).

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caused by glaciation might well be expected in a deposit overlain by glacial drift and they are substantiated by structures noted at the east end of the deposit where the sand is mixed to some extent with glacial till. This locality is close to the outcrops of the Carboniferous coal and gypsum, and the sand besides being contorted carries flakes of coal and small aggregates of grains cemented by pyrite.

Another indication of movement occurs near test-hole No. 5. Here a seam of red clay dips 52 degrees west and cuts across the normal dips. At its intersection with a carbonaceous layer the latter is dragged and displaced 5 or 6 inches. Only a single instance of this character was noted.

Small lenses or blebs of fairly pure clay are common in some of the sand layers, but are too small to be of importance, except in so far as they affect the clay content of the sand. Occasional carbonaceous streaks, lenses, and seams follow the structures of the beds, but are not continuous for any distance. This material is very friable and seldom exhibits original structures, although an occasional woody piece may be seen. These seams form channels for circulating waters, and are characterized by the rusty colour of ferric iron. Ferric iron is also deposited where sand overlies or grades downward into clay.

In the vicinity of the large excavation (test-hole No. 13), masses of sand grains, cemented by ferric iron, are fairly numerous. These are characteristic only of the sand, although not confined to any particular bed. The shape is roughly globular, and the average diameter is about $1\frac{1}{4}$ inches. Compound globules give larger sizes and more irregular shapes. The sand near these bodies is stained yellow, but the masses themselves are red or brown. They are hard enough to resist sharp blows with a hammer. Sections made show an outer crust of sand cemented by hematite, from one-eighth to one-half inch thick, and an interior filled with sand cemented by limonitic material. The interior is soft and may be scraped out with any sharp instrument. There appears to be little doubt that these bodies are concretionary, and, according to their occurrence, composition, and structure, they would be classed as "excretions",¹ although no central nucleus was noted. In comparison with the sand, their size and colour permit easy separation and removal during the process of mining.

SAMPLING AND TESTING

Owing to the nature of the excavations, sampling of the deposit was by no means thorough. In only three excavations was the sand exposed in such a way that samples could be obtained from individual beds. Each sample, about 5 pounds in weight, was as representative of a bed as was possible. Five-pound samples were also taken from the ends of the tunnels on the north side of the brook.

Test borings with an 8-foot auger were made by the author at a number of points, but in many cases it was not possible, owing to the compactness of the sand, to drive the auger to its full extent. The oper-

¹Grabau, A. W.: "Principles of Stratigraphy", New York, 1913, pp. 718-721.

drift. At test-
hole No. 13, the
sand is thoroughly
mixed with glacial
drift. The
structures and
the clay content
were not of
importance.



Fig. 1. E. Wilson
is shown
sand, No. 4
sand, No. 7
contains clay

secondary series
(No. 21). These
sand inter-
bedded planes
do not exhibit
evidence of these
spiral during
the result of
a common
the move-
ment of the
structures

do not show
structural changes

ators collaborated in this testing, using pipe and a small hand-operated churn drill. In this way greater depth was obtained. The data with respect to these test-holes are given below.

Hole No.	Type of hole	Depth in feet	Material	Cover in feet	Depth of cover in vicinity in feet
1	Auger	5-6	Red clay	Not shown	on map
2	"	7	Red gravel		
3	"	6	Sand		
4	"	8	"		1
5	"	8	"		2-5
6	"	6	"		4
7	"	5	"		4
8	"	7	"		3
9	"	7	"		3
10	"	5	"		3-4
11	Pipe	21	"	1	1
12	"	20	"	1	1
13	Churn drill	31	"		3-4
14	Pipe	19-5	"		4-6
15	Auger	5	"	2	2
16	"	7	"	4	4
17	Pipe	20	"		3-4

A further series of ten auger holes was made at the eastern end of the deposit, but the exact location of each was not determined. Their approximate location is shown on the map. Sand was reported from all these.

The larger samples were tested for clay content and were also subjected to a screen analysis. The procedure was as follows:

The sample was cut down to about 75 grammes in weight. This was dried for one hour at a temperature between 105° and 110° C. A 50-gramme portion of the dried sample was placed in a glass jar with 475 cubic centimetres of water and 25 cubic centimetres of a solution of sodium hydroxide (10 grammes in 1,000 centimetres). The jar was then sealed and agitated in a mechanical device for one hour, allowed to stand ten minutes, and the suspended material siphoned off. The jar was again filled with water, and at the end of ten minutes again siphoned. Water was added again, and at the end of five minutes siphoned off. The process of five minutes standing and siphoning was repeated until the water was clear at the end of the period. The residue was then filtered, dried, and weighed, and the loss, calculated to per cent, is called clay-substance.

The dried residue was next placed in the first of a series of screens (Tyler's Nos. 10, 20, 28, 35, 48, 65, 100, 150, and 200) and the sieve-nest placed in a Ro-Tap testing machine, which was run for twenty minutes. The amounts remaining on each screen were weighed and expressed in per cent. That passing through the 200-mesh screen is known as -200. The results of these tests are given below.

Sample No.	244	279	291	299	300	284
Clay-substance	%	%	%	%	%	%
on 200	6.7	4.0	6.5	16.8	10.9	11.8
on 150	2.1	2.8	2.2	7.9	3.4	3.2
on 100	0.9	1.3	0.6	4.4	1.5	1.1
on 65	3.0	2.6	1.6	10.9	4.0	4.0
on 48	11.9	11.6	5.6	22.8	12.2	14.5
on 35	24.0	12.4	9.9	19.3	29.0	20.5
on 25	25.5	27.0	16.9	11.0	25.9	19.7
on 20	16.1	25.6	26.3	4.9	10.1	14.2
on 10	4.1	7.8	15.7	1.0	2.2	5.6
Loss	3.7	3.2	9.7	0.4	0.4	3.8
	0.7	0.1	1.8	0.0	0.0	0.3
	1.7	0.5	1.1	0.5	0.2	1.3

No. 244, end of long tunnel; 279, near test-hole No. 13; 291, near test-hole No. 5; 299, near test-hole No. 9; 300, near test-hole No. 9; 284, test-hole No. 8.

The screen analyses show that the bulk of the sand lies between 35 and 65 mesh and that the finer sands, as might be expected, carry the higher proportion of clay-substance. As the samples are believed to be fairly representative, the deposit as a whole should average about this grade. The loss during screening is attributable to two causes, viz., handling and adherence to the screens.

The washed and dried sand after screening was examined under a microscope, both in air and in index liquids. By means of bromoform the heavier minerals were separated from sample No. 290. Although some quartz and mica settled with the heavy residue, the total proportion of heavy minerals by weight did not exceed 0.5 per cent.

MINERALOGY

Under the microscope the individual sand grains exhibit angular to sub-angular outlines, increasing in angularity in the finer sizes. Mica was present in fairly constant proportions in all the specimens examined. Owing to the difficulty of handling the extremely fine flakes, no attempt was made to calculate the proportions of this mineral. Soluble constituents are scarce and probably do not exceed 0.5 per cent. Specimen No. 290 was treated for twenty minutes with hot, dilute HCl (1:10). The loss was 0.4 per cent.

QUARTZ

Quartz is the most abundant mineral in the sand. It exceeds in quantity all the other minerals, and although in places the clay-substance may exceed it in amount, such occurrences are not numerous.

Two varieties of quartz were noted, both of which occur throughout all sizes of the sand. The most abundant variety is white and of more even dimensions than the second, which is glassy, clear, and is characterized by conchoidal fractures with acute edges. Both varieties are angular below 100 mesh, but above that figure rounding and polishing become evident.

The white grains, although of irregular surface, show good rounding at 65 mesh, whereas the clear grains do not exhibit much rounding and polishing below 35 mesh.

On mounting the grains in either Canada balsam or clove oil, the reason for the difference in appearance becomes evident. The white grains are very dusty, with minute crystalline, gaseous, and liquid inclusions, whereas dustiness in the clear grains is not nearly so pronounced. The latter also exhibit etched and modified crystal faces. Composite quartz grains may occasionally be noted, especially among the finer sand grains. For the most part these are inclined to be elongate and in appearance resemble the quartz grains of some schists and gneisses which have been granulated and broken.

CLAY-SUBSTANCE

The word "clay-substance" is used to indicate the material which was washed out of the sand by successive decantations and, although not strictly a mineral, it may be considered under this head. Much of the decanted material settled within half an hour from the time of siphoning, but a considerable proportion remained in suspension for twelve hours, and it was found necessary to effect its coagulation and settling with sodium chloride.

The composition of the clay-substance was not determined, but it undoubtedly carries silica in a finely divided, if not colloidal, state, as well as microscopic flakes of mica and true kaolin.

Tests,¹ made on clay from this locality and published in the previously quoted report by Ries and Keele, are given below.

Laboratory No.	Field No.	Locality	Water required	Air shrinkage
1580	57a	Red clay, Diogenes brook, C.B.	19	6.6
1581	57b	White clay, Diogenes brook, C.B.	22	6.3
1583	57d	Blue clay, Diogenes brook, C.B.	20	7.0

Laboratory No.	Cone 010			Cone 03		
	Fire shrinkage	Colour	Absorption %	Fire shrinkage	Colour	Absorption %
1580	-0.9	red	13.66	0.0	pink	12.03
1581	0.1		13.72	1.0		12.41
1583	-0.2		11.97	4.0		6.73

MICA

Mica is found in all the sands examined and is also present in the clay beds. The most common type resembles muscovite and occurs in clear flakes of all sizes down to and below 200 mesh. This mineral was a source

¹Geol. Surv., Canada, Appendix I: "The Clay and Shale Deposits of Nova Scotia and Portions of New Brunswick", Mem. 16 (1911).

sharply from the chocolate colour of the overlying drift and the presence of the hematite concretions suggests a certain amount of subaerial exposure to leaching action before the drift was deposited.

The data noted are not such as would easily aid in the determination of any one of these phenomena and at the present time the writer does not feel justified in assigning either a deltaic, torrential, or glacial origin to the deposit.

The original source of the material and its history previous to the time that it was laid down are not easily deciphered. Since the sand is known to overlie the eroded Carboniferous sediments in the bottom of the brook, it is clear that the sand was deposited after the granitic and older rocks had been uncovered and after the Craignish hills had assumed somewhat their present form. Therefore, the stream that deposited the sand was probably not much longer than the present Diogenes brook, whose sources are not more than $1\frac{1}{2}$ miles above the sand deposit. It is believed, therefore, that the materials of the deposit must have come from within this radius.

The constituents of the sand are largely such as would be afforded by the weathering of the granite and presumably were so produced, but the clear quartz grains are not characteristic of either the granites or the quartzites, and these constituents at least were probably derived from some other rock type. The white mica is probably derived from the granite either by direct weathering or from the breaking down of the feldspars. The heavy minerals are not reliable criteria for either igneous or sedimentary rocks, but from the angularity of the grains the latter possibility appears to be the least feasible. The data point to the granitic rocks as the most likely source of the sand, but in an area of complex structure it would be strange if one rock type should contribute all constituents. It is concluded that the sand is mainly the result of the decomposition and decay of the granitic rocks of the immediate neighbourhood and that it was deposited in the valley by stream action.

AGE OF THE DEPOSIT

Data relating to the age of the deposit are extremely meagre. Ries and Keele in their previously cited report classify this occurrence with several others under the heading "Pleistocene Clays", but give no evidence in support of this classification. It is evident that the sand is older than the drift which overlies it; but if there have been two advances of the ice, as the evidence at times seems to indicate,¹ the sand may represent a delta deposit, built during a glacial interval and preserved by reason of its position. In this case there might be another drift sheet below the sand.

Pre-Glacial sands and clays, referred to the Mesozoic, have been reported from the Musquodoboit valley, Nova Scotia, and are believed to be estuarine in origin.² Other unconsolidated marine deposits of sand and clay underlie the glacial drift of the Atlantic coastal plain. They carry glauconite, and from the structural and faunal evidence are referred to the Tertiary and Upper Cretaceous.³

¹Goldthwait, J. W.: "Physiography of Nova Scotia"; Geol. Surv., Canada, Mem. 140, pp. 80-103 (1924).

²Ries and Keele: op. cit., pp. 73-87.

³Bowman, L.: "Atlantic Pre-Glacial Deposits"; Am. Jour. Sc., ser. 4, vol. 22, pp. 313-323 (1906).

Fuller, M. L.: "The Geology of Long Island, New York"; U.S. Geol. Surv., Prof. Paper 82 (1914).

Little information bearing upon the age of the deposit is available from the contained carbonaceous material. A few fragments of wood were collected from the beds at the eastern end of the deposit where the sand, either through slumping or deformation, is to some extent involved with the glacial drift. The best of these was submitted to Professor C. C. Curtis of the Department of Botany, Columbia University, who kindly identified it as a species of hemlock. Although this genus is not a reliable criterion for an age determination, some of the features are significant. The fragment, showing the heart of the tree, is about an inch in diameter and on this surface the writer counted no less than fifty annual rings. The density of these rings, indicative of slow growth, leads to the supposition that the tree did not grow in a warm or temperate climate. If the specimen is actually from the sand and not from the glacial drift the evidence would appear to favour an age not far removed from the Pleistocene, but the presence of such a specimen is given little weight in assigning an age to the deposit.

The lithologic evidence may serve to place the age as either Cretaceous or Tertiary. The stratigraphic evidence, however, signifies nothing more definite than a pre-Glacial age.

PRODUCTION AND DEVELOPMENT

The production of sand by the River Denys Sand and Clay Company has not been large; but taking into consideration the long haul and the difficulties attendant upon the building up of a business, each year's production has shown a satisfactory increase over the previous one.

The production by years is as follows:

	Tons
1923.....	
1924.....	400
1925.....	1,500
1926.....	1,000, to Sept. 10

Active mining is carried on only from May to October. During the season of 1926, twenty-five men were employed and seven 1-ton Ford trucks were in constant use between the workings and the railway. The average load per truck was a little over one ton.

Mining at present is carried on by hand, the sand being loaded into coal trucks in the tunnels, or shovelled directly into the Ford trucks from the open excavations.

Before sand can be extracted by open mining, it is necessary to clear the standing timber from the locality selected and then remove the glacial drift, which so far has not exceeded 20 feet as a maximum, and generally has been about 3 or 4 feet. No great difficulty has been encountered from slides.

Where mining is carried on by means of tunnels, the sand of the quality desired is allowed to flow into the opening and is removed as required. It is necessary to lag the tunnels throughout, and advance is made by forepoling, square sets being used, as the lateral pressure is found to be heavy.

If properly constructed the tunnel appear to stand well. The longest tunnel was not used or repaired during the summer of 1926 and was open on September 20 of that year.

POSSIBILITIES

The future of the deposit depends on several factors, chief among which are the extent of the deposit, the behaviour of the sand under actual working conditions in a foundry, and economic factors such as cost of mining, freight rates, etc.

The size of the deposit cannot as yet be determined. An attempt was made by the author to estimate the volume outlined at present, from data obtained during the examination. This was done by calculating the areas of a mean, and an average, cross-section of the deposit and multiplying these figures, respectively, by a length of 800 feet. Another calculation was made on a plan view by joining the various test-holes together to form a series of triangles and computing the volume of sand in each. The results of these calculations reduced to tons are 127,000, 122,000, and 139,000 respectively. The calculations thus indicate that within the tested part of the deposit there are 120,000 to 140,000 tons of sand. These figures at best are only a very rough approximation and it is probable that the tonnage of the whole deposit is far greater.

The behaviour of the sand under actual working conditions appears to be quite satisfactory. Replies from letters addressed to several of the firms now using the sand and clay indicate that the sand is equal to the previously used imported sands, and that the clay appears to be perfectly satisfactory for stoneware, Rockingham, and yellowware. It should be pointed out, however, that mica, in more than a very small proportion, is a very undesirable constituent of moulding sands, as it greatly reduces the refractoriness. This fact should be carried in mind as the mica content of this sand may prohibit its use for certain moulds.

The difficulties attendant upon mining may prove important factors in the cost of production. It may be that, as the deposit is worked, the thickness of the glacial drift will so increase that tunnelling will have to take the place of the open workings now used. The difficulties which will arise when mining has progressed below the level of Diogenes brook must also be considered. It was noted during the testing that water entered the low test-holes as soon as they were 2 or 3 feet below the surface, indicating a shallow and mobile water-table. The width of the valley will not permit the brook to be diverted except near the headwaters, and if difficulties are met from this source it will be necessary to devise some other method to take care of the water.

(17)

Inverness County

Laboratory Nos. 138, 139

Locality. Mainly on the north bank of Diogenes brook, 4 miles north-west from the village of Melford or 10 miles from River Denys on the Canadian National railway.

Owncr. River Dennis Sand and Clay Company, Ltd., Melford, N.S.

Operator. The same. Manager, J. A. McLellan.

History. The deposit first became known about 1886, but no development was done until about 1911. In 1917 it was acquired by the present owners. By 1924 development was such that it was necessary to build the four-mile road connecting the deposit with the Victoria road at Melford. In 1928 the company was being reorganized, additional capital was sought, and it was hoped that in the not distant future a branch line of the railway would be built to save the excessive cost of hauling by one-ton trucks to River Denys Station.

Description. The property is described in detail by T. D. Guernsey¹. An account also appears in a provincial report.² An earlier résumé is by Heinrich Ries and Joseph Keele.³ Only a brief description is given here.

The deposit lies within the steep sides of the valley of Diogenes brook. Owing to the increase in the overburden of unstratified glacial drift from a minimum thickness of 3 or 4 feet near the brook level to a maximum of about 20 feet at the top of the slopes, development so far has been confined to the valley bottom. Of the 95 acres that the company owns outright, or adjoining property of which it holds leases, only a very small area has had any work done upon it. There are pits in at least seven places. Three adits have been driven through the top of the hillsides near the pits and a small tramway runs from one pit across the brook to the road. All excavation has been done by hand.

There are different grades of the sand, which occurs generally in cross-bedded layers, interspersed occasionally with irregular beds of creamy white clay, like kaolin. The property was not visited by the writer. Sample No. 138 was collected by E. H. Wait in 1929 and sample No. 139 by L. Heber Cole in 1930, both of the Mines Branch, Department of Mines.

Market. The sand, which is very suitable for the casting of steel products, has been sold in Sydney and New Glasgow replacing imported sands. The demand for it has grown since the first shipments were made about 1924. Some of the interbedded clay has found application in the pottery industry at St. John, N.B.

Remarks. The sand has extraordinary refractory power and the clay substance extracted from the sand shows equal refractoriness. The clay has little plasticity or bonding power while in a moist state, but moulds

¹ Geol. Surv., Dept. of Mines, Canada, Sum. Rept. 1926, Part C, pp. 110-124.

² Nova Scotia Mines Report, 1927, Part I, pp. 132-140.

³ Geol. Surv., Dept. of Mines, Canada, Mem. 16-E, pp. 65-66.

made from the sand and dried have remarkable strength. The compressive strength of the sand as given in the tables is for dry sand moulds and not for those of the green sand, as given for other sands.

Kings County

Laboratory Nos. 31, 32

Locality. On a projection of land known locally as "Oak Island," $1\frac{1}{2}$ miles north of Avonport. It is also $\frac{1}{4}$ of a mile north by private road from a crossing on the Dominion Atlantic railway.

Owner. Imrie J. Borden, Avonport, N.S.

Description. Prospect samples were collected on this peninsular-shaped piece of land jutting into Minas basin, at an approximate elevation of 25 feet. Most of the higher land is covered with bush; a little is cultivated, and that where the samples were dug was cleared. Two samples were taken at spots 265 feet apart, sample No. 31 being collected north-eastward from where sample No. 32 was found. Sample No. 31 represents a layer of moulding sand 18 to 21 inches thick, and underlain by a coarser grained sharp sand. Sample No. 32 is from a bed of moulding sand 16 to 18 inches thick, and beneath this is a sharp sand finer grained than that below where sample No. 31 was taken. The overburden through this entire tract of land is uniform and of a thickness of only about 9 inches. Two or three acres is the area estimated as most likely possessing grades of moulding sand similar to the samples. Mr. Benton Borden was present when the samples were collected, in July, 1928.

Market. A trial shipment of the sand represented by sample No. 31 was submitted to a foundry in Nova Scotia about 1922, but as it apparently did not meet requirements no order was received. The nearest foundry to the deposit is at Windsor, N.S., a distance of 12 miles. Avonport Station on the Dominion Atlantic railway is distant $1\frac{1}{4}$ miles. Trucks could be used on the connecting road.

Remarks. The sand represented by sample No. 32 is considered the better of the two. Although, according to the mechanical analysis, it has less clay substance, what there is of it is of a more plastic nature and its refractoriness is high.

Laboratory No. 41

Locality. On the property of the owner in Kentville.

Owner. Lloyd Manufacturing Co., Ltd., Kentville.

Operator. The same.

History. This moulding sand deposit was discovered about 1898 while making excavations for the foundry buildings. It has been used ever since.

Property of:

Technical Records Library

TABLE VIII
Mechanical Analyses of Sands from Nova Scotia and New Brunswick
NOVA SCOTIA

Laboratory No.		Locality, county	Screen Analysis, percentages															Grain No.	Clay Class	Moisture (temping.) Percentage	Permeability	Compressive strength (lb per sq in)	Refraction index equivalent Sand Clay	Color
			Screen numbers: top line, Tyler; bottom, U. S. Bureau of Standards																					
			On 6	On 10	On 20	On 30	On 40	On 60	On 80	On 100	On 150	On 200	On 250	On 270	On 280	On 300	On 325							
34	Colchester	0.20	0.21	0.36	0.64	1.69	6.12	11.77	13.40	13.16	11.93	32.78	5.4	100.7	183	D	(6.2)	12.6	3.1	12.2	3.1	Nil	Nil	
35	"	1.09	2.06	3.33	5.13	8.59	8.07	0.67	0.36	7.11	7.88	23.25	16.6	99.9	144	F	(4.0)	4.2	7.0	7.5	15	11	Nil	
36	Cumberland	0.30	0.08	0.05	0.03	0.21	0.11	0.10	0.14	0.42	5.59	88.39	4.9	100.3	291	C	(4.2)	6.6	3.2	1.1	11	11	Nil	
28	Hants	...	0.13	0.98	4.40	11.94	18.60	17.03	11.34	6.84	6.50	11.17	11.9	100.5	106	F	(4.0)	10.4	5.3	1.5	11	12.4	Nil	
29	"	0.04	0.82	2.21	6.40	11.16	18.45	17.54	10.54	6.01	5.12	10.94	8.9	100.0	101	D	(4.0)	23.2	4.2	2.1	15	12.4	Nil	
30	"	...	0.18	0.81	0.66	1.40	3.04	7.20	11.12	11.14	12.60	32.50	18.9	99.6	195	F	(6.1)	3.1	11.9	11.3	13	12	Nil	
138	Lawrence	0.14	1.28	5.74	16.86	30.18	17.08	12.94	6.00	1.56	0.78	1.20	6.2	100.0	53	S	(7.2)	243.6	3.9	39.1	39.1	30.1	Nil	
139	"	...	0.10	1.14	5.40	21.90	31.76	17.82	5.32	1.92	1.14	2.40	11.3	100.0	64	F	(3.9)	133.3	3.9	40.3	40.3	30.1	Nil	

31 Kings	0.39	1.21	2.60	3.19	3.94	8.73	11.47	12.84	11.55	14.45	23.27	5.0	98.7	154	2	D	(4.3 15.6 7.9	12.9 3.1 16.8	3.1 3.1 4.4	Nil
32 "	0.39	0.69	0.82	1.12	1.62	3.06	6.26	9.41	11.91	18.67	39.99	7.3	101.5	162	2	D	(4.2 6.1 9.1	8.1 10.6 16.9	4.4 4.9 4.8	16
41 "	0.18	0.36	0.52	1.02	2.44	8.34	16.53	17.91	12.91	11.87	17.82	9.5	99.6	146	2	D	(4.0 5.9 13.8	8.3 13.8 6.5	5.3 6.5 5.0	15

NEW BRUNSWICK

39 Kent	0.10	0.40	0.76	1.43	3.39	7.17	13.14	14.87	11.31	11.56	30.80	5.1	100.2	170	2	D	(6.3 8.0 10.3	4.0 7.1 8.2	4.9 5.5 6.7	11
40 St. John	0.23	0.41	2.08	10.33	29.56	36.30	6.00	6.00	1.60	1.63	6.25	5.4	99.8	80	4	D	(4.0 6.0 9.4	21.3 24.0 11.7	3.6 4.0 3.7	Nil
37 Westmorland	0.39	1.01	0.91	1.54	3.12	5.61	16.60	22.57	14.87	11.72	20.36	2.3	101.1	146	2	C	(5.9 7.8 10.0	12.8 15.8 29.2	3.4 4.3 4.1	Nil
38 "	0.85	0.82	0.70	1.35	3.07	5.56	12.37	19.49	13.64	11.30	26.13	6.6	100.9	161	2	D	(4.0 6.2 9.0	6.8 13.8 18.6	2.6 3.6 4.3	104

DIOGENES (GLEN) BROOK SILICA SAND PROPERTY

This deposit is 20 miles (32 km) north of Port Hawkesbury. A four mile (6.4 km) logging road following Diogenes Brook and connecting with the Trans-Canada Highway (No. 105) at Melford, Inverness County provides access to the property.

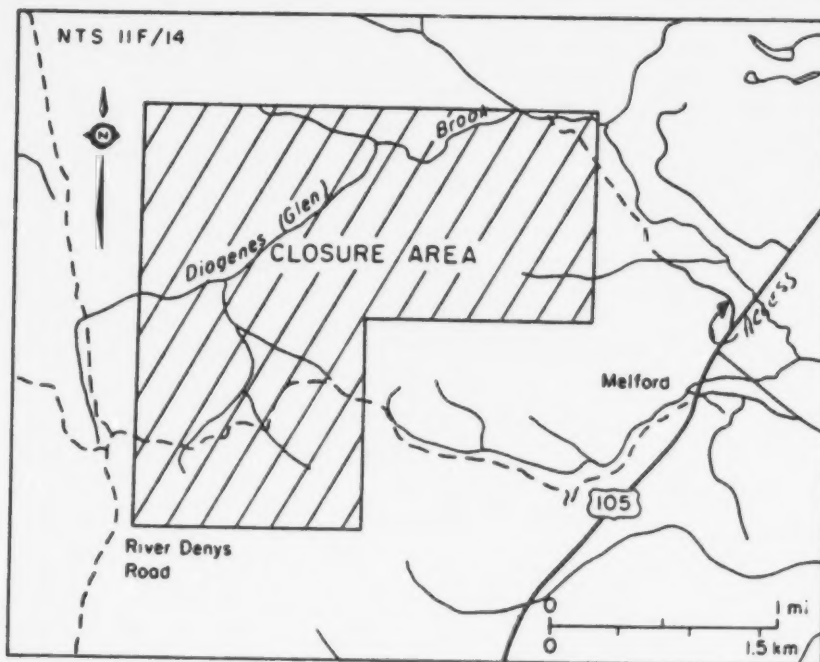


Figure 4. Location of the Diogenes Brook closure.

This deposit was known for several years prior to its development in 1917 by The River Denys Sand and Clay Company Limited. The first published information appears in The Clay and Shale Deposits of Nova Scotia and Portions of New Brunswick by H. Ries and J. Keele (1911) who described it as a light coloured clay deposit interstratified with white sand.

Guernsey (1926) travelled to Diogenes Brook and was able to inspect the sands and clays in pits and adits developed for mining silica sand by The River Denys Sand and Clay Company. This company was selling foundry sand to several customers in Nova Scotia and shipping some clay to a pottery firm in Saint John, New Brunswick. Guernsey, provided an excellent description of the deposit and mining activities and noted that the deposit was bedded, that it was in sharp contact with the overlying younger glacial deposits and that the beds were steeply dipping.

Carnochan (1931) completed tests on sand samples from this deposit and concluded that by washing and screening a good blast sand could be recovered and by washing, tabling and screening a sand suitable for making clear glass could be recovered from the coarse fraction. Freeman (1936) indicated that the sand is suitable for the casting of steel products.

Dickie (in prep.) reported "Three holes were drilled into the Diogenes Brook sand deposit to determine the thickness of sand and clay in the valley. The first hole was collared in white silica sand and drilled predominantly sand to a depth of 302 feet (92 m). From that point to bedrock at 390 feet (119 m), dark grey plastic clay and lignite were cored. The bedrock comprises a white to grey mudstone breccia.

The other two holes were drilled to determine the lateral continuity of the sand and determined that the top of the Cretaceous sand was virtually flat and overlain by thick terraces of Pleistocene sand, gravel and till."

Work done by Dickie (in prep.) at Diogenes Brook suggests the deposit may contain 7.7 million tons (7 million t) of silica sand grading over 95% SiO₂.

Table 1. Chemical analyses (expressed in percent) of silica sand samples from drillholes, Diogenes Brook, 1982.

Sample	SiO ₂	Fe ₂ O ₃ (Total Fe)	Al ₂ O ₃	TiO ₂	S	
Hole #1	5-8M	93.5	0.62	3.17	0.20	.003
	8-14M	97.2	0.59	1.23	0.08	.002
	14-17M	97.0	0.70	1.42	0.08	.003
	17-20M	97.7	0.41	1.21	0.06	.018
	20-23M	93.0	2.06	2.12	0.35	.009
	23-26M	94.4	2.40	1.73	0.12	.024
	26-29M	97.9	0.48	0.76	0.04	.001
	29-32M	98.0	0.89	0.44	0.14	.004
	32-35M	96.4	0.79	1.25	0.12	.002
	7-11M	80.2	3.29	6.54	0.47	.032
Hole #2	11-14M	92.2	1.82	2.22	0.13	.013
	14-17M	97.0	0.53	1.17	0.12	.089
	17-20M	97.7	0.41	1.23	0.06	.016
	20-23M	97.9	0.61	0.81	0.07	.010
	23-26M	98.2	0.51	0.79	0.06	-
	26-29M	97.6	0.61	1.08	0.08	-
	4-5M	95.3	0.66	0.91	0.18	.035
Hole #3	5-8M	97.9	0.54	1.40	0.10	.042
	8-11M	96.9	0.45	2.04	0.27	.085
	11-14M	94.7	0.68	1.44	0.11	-
	14-17M	96.4	0.51	1.40	0.13	-
	17-20M	96.4	0.96	2.16	0.13	-
	20-23M	94.4	0.96	2.14	0.47	-
						-

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WASHING AND MAGNETIC SEPARATION TESTS

ON

MUSQUODOROTT SAND SAMPLES

Nova Scotia Technical College,
Halifax, Nova Scotia

October 8th, 1969

M. A. K. Grice
.....
M. A. K. Grice
Project Director.

INTRODUCTION

During exploratory drilling operations in the Musquodoboit Valley several sand beds were intersected and these tests were conducted to see what grade of silica sand could be produced from them.

SAMPLES

Equal quantities of the following samples were blended to give a reasonable representative sample to work with.

83/1	104/-	106/1	106/6	109/1	109/2
110/2	111/3	113/3	117/2	117/2*	117/3*
117/4*	117/5*				

*These samples had already been washed but were included to give a more representative sand product after washing.

PREVIOUS ANALYSES OF SAMPLES FROM THIS DEPOSIT

<u>Drill Hole No.</u>	<u>Unwashed</u>		<u>Washed</u>	
	<u>% Silica</u>	<u>% L.O.I.</u>	<u>% Silica</u>	<u>% L.O.I.</u>
EL. 83/1	96.5	-	96.6	-
EL. 105/1	98.0	-	98.3	-
EL. 106/1	92.9	-	97.0	-
EL. 106/6	97.3	-	95.3	-
EL. 108/1	92.5	-	-	-
EL. 109/1	94.0	-	-	-
EL. 109/2	89.0	-	-	-
EL. 116/182	88.2	1.5	-	-
EL. 116/3&4	85.9	1.7	-	-

EL 116/5&6&7	88.3	3.1	-	-
EL 117/2	-	-	98.6	-
EL 117/3	-	-	98.4	-
EL 117/4	-	-	98.5	-
EL 117/5	-	-	98.0	-

WASHING TEST

A 2000 gram sample was mixed with 2000 ccs. of water and scrubbed in a Denver Flotation Cell for 5 minutes, then as much water as possible was decanted off. A further 1500 ccs. of water was added and the sample scrubbed again for 3 minutes and then decanted. The latter step was repeated three times.

The sand sample was then drained and dried in the oven. A settling test was done on the 'washings', then they were wet screened on a #200 mesh screen and the products dried in the oven. After drying, the sand and the #200 mesh washings were dry screened.

	<u>Gms.</u>	<u>Wt.</u>	<u>Analyses %</u>			<u>Distribution %</u>		
		<u>%</u>	<u>SiO₂</u>	<u>Fe</u>	<u>Al₂O₃</u>	<u>SiO₂</u>	<u>Fe</u>	<u>Al₂O₃</u>
Head Sample	1942	100.0	-	-	-	-	-	-
Washed Sand	1472	75.8	98.1	0.76	0.57	78.4	40.6	22.6
Washings #200 Mesh	262	13.5	97.6	0.90	0.89	13.9	8.5	6.2
Washings -200 Mesh	208	10.7	68.4	6.80	12.80	7.7	50.9	71.2
Head Calc.	-	-	94.1	1.43	1.92	100.0	100.0	100.0

There was a considerable amount of mica visible in the #200 mesh washings.

SIZE ANALYSES AND ASSAYS OF PRODUCTS

Washed Sand Fraction After Magnetic Separation

<u>Mesh</u>	<u>% Wt.</u>	<u>Assay</u>		
		<u>SiO₂</u>	<u>Fe</u>	<u>Al₂O₃</u>
# 14	13.4	98.4	0.66	0.45
-14 # 28	34.1	98.6	0.69	0.40
-28 # 48	35.6	98.3	0.65	0.30
-48 #100	11.4	98.5	0.69	0.35
-100 #200	4.9	97.4	0.75	0.69
-200	<u>0.6</u> 100.0	<u>84.5</u>	<u>4.50</u> 0.70	<u>4.30</u>

"WASHINGS"

<u>Mesh</u>	<u>% Wt.</u>	<u>Assay</u>		
		<u>SiO₂</u>	<u>Fe</u>	<u>Al₂O₃</u>
# 48	3.0)	97.6	0.90	0.85
-48 # 100	28.7)			
-100 # 200	24.0)			
- 200	44.3	68.4	6.80	12.80
	<u>100.0</u>			

WASHED SAND

(Additional Assays)

<u>L.O.I.</u>	<u>CaO</u>	<u>MgO</u>
Less than 0.1	0.18	0.10

QUALITY EXPECTED OF A GLASS SAND

(Extracted from "Industrial Rocks and Minerals" 1949 Edition)

SIZE ANALYSES

<u>Mesh</u>	<u>% Retained</u>		<u>Musquodoboit Sand</u>	
	<u>Recommended</u> ⁽¹⁾	<u>Average 11 Glass Sand</u> ⁽²⁾	<u>As Washed</u>	<u>#20 Mesh Removed</u> ⁽³⁾
# 20	0	0.2	28.1	0.0
-20 # 35	40 - 60	14.4	38.1	52.9
-35 # 60	30 - 40	45.6	23.3	32.4
-60 # 100	10 - 20	32.2	5.0	7.0
-100	0 - 5	7.6	5.5	7.6

(1) Recommended by American Ceramic Society and the National Bureau of Standards.

(2) Sands listed Table 5, Page 972.

(3) Calculated Size Analysis.

MAGNETIC SEPARATION

Each size fraction from the screening of the sand portion were passed separately through the Carpc Dry Magnetic Separator running at 50 r.p.m. and a magnetizing current of 2 1/2 amps.

<u>Mesh Size</u>	<u>% Wt. Magnetic Concentrate</u>
# 14	N11
- 14 # 20	0.6
- 20 # 48	1.1
- 48 #100	3.5
-100 #200	4.2
-200	Insufficient sample for test.

Due to the small amount of magnetic concentrate from each test they were all combined for the chemical analysis.

<u>% SiO₂</u>	<u>% Fe</u>
66.1	14.0

Total magnetic concentrate was 1.2% of washed sand so the magnetic separation would reduce the iron content by 0.16%

CHEMICAL ANALYSES

Specifications for Chemical Composition of Glass Sand
PERCENTAGE COMPOSITION BASED ON FINED SAMPLES

Qualities	SiO ₂ Mini- mum	Al ₂ O ₃ Maxi- mum	Fe ₂ O ₃ Maxi- mum	CaO + MgO Maximum
First quality, optical glass	99.8	0.1	0.02	0.1
Second quality, flat glass containers and tableware	99.5	0.3	0.033	0.2
Third quality, flat glass	99.0	4.0	0.033	0.3
Fourth quality, sheet glass, rolled and polished plate	98.5	0.5	0.08	0.3
Fifth quality, sheet glass, rolled and polished plate	98.0	4.0	0.08	0.3
Sixth quality, green glass containers and window glass	98.0	0.8	0.3	0.3
Seventh quality, green glass	95.0	4.0	0.3	0.3
Eighth quality, amber glass containers	98.0	0.3	1.0	0.3
Ninth quality, amber	95.0	1.0	1.0	0.3

With washing and screening the Musquodobit Sand would fall into the eighth quality bracket, "amber glass containers" although the iron content is slightly exceeding the maximum Fe₂O₃ at 1.08%.

CONCLUSION

A eighth grade glass (Amber glass containers) can be produced from the Musquodobit Sand by simple washing and screening treatment. Magnetic separation improves the quality slightly and may be necessary depending upon the customer's requirements.

RECOMMENDATIONS

If any regional glass company could be interested in the possibility of using this sand, a sufficient quantity should be run through the N.S.T.C. Pilot Plant to allow customer evaluation and acceptance tests to be carried out.

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NOVA SCOTIA DEPARTMENT OF MINES

SILICA SAND DEPOSITS OF THE
MUSQUODOBOIT VALLEY, HALIFAX COUNTY
AND
SPECIFICATIONS AND USES OF SILICA SAND

BY

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AUGUST 1969

* Chief Geologist, Department of Mines

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CONCLUSIONS

INTRODUCTION

For the past two years the Geological Division of the Nova Scotia Department of Mines has carried out an extensive investigation of the clay deposits in the Musquodoboit Valley, Halifax County. During this program 115 drill holes have been completed on various clay deposits and in a search for hidden deposits. Many of the drill holes penetrated silica sand. It occurs overlying, interstratified with and at the base of the clay. In several areas silica sand is exposed at the surface and under a shallow covering of glacial drift.

Production of industrial silica sands in Nova Scotia amounts to a little over 2,000 tons per year and for construction purposes over a million tons. There are many known deposits of silica sand in Nova Scotia but to date they have not been adequately investigated. Many requests are received for information on the possibilities for major production of high quality silica sand.

The Canadian and United States market for high grade silica sand is wide and investigations being carried out suggest that it may be possible to beneficiate some of the silica sand deposits in Nova Scotia to produce a product suitable for the requirements of the glass and ceramic industries.

This report gives the specifications and uses of silica sand and outlines the results of tests made on the silica sand deposits encountered during exploration of the clay deposits in the Musquodoboit Valley, Halifax County.

SPECIFICATIONS AND USES OF SILICA SAND

(1) Silicon Carbide

Silica sand used for silicon carbide manufacture should have a minimum silica content of 99.25 percent. Lime, magnesia and phosphorus are objectionable. The iron and alumina should be less than 0.1 percent each. A grained sand is preferred for silicon carbide manufacture, but finer sands are sometimes used. All sand should be plus 100 mesh, with the bulk of it plus 50 mesh in size.

(2) Silica Brick

The silica content of the quartz used should range from 95 to 98 percent. The iron and alumina should be less than 1 percent each and other impurities, such as lime alkalis and magnesia, should be low. Combined iron and alumina under 1.5 percent.

Silica bricks have a high load bearing capacity at elevated temperatures and consequently have been widely employed for spring arches used as roofs for open-hearth furnaces, glass tanks, kilns and coke ovens. Bricks are manufactured from quartz containing about 95 percent SiO_2 to which is added some 2 to 3 percent of lime. The added lime serves as a mineralizer during firing. Fired brick consists of shattered quartz grains that have been almost completely transformed into cristobalite (starting at the edges of the grains) in a matrix of fine tridymite, cristobalite and glass. Small amounts of unconverted quartz (about 1%) normally remain with nearly

amounts of cristobalite and tridymite formed. Excessive quartz (frequently present in brick at one time) is deleterious because of the large volume change accompanying the alpha to beta transformation at 573°C .

Long firing times normally tend to favour tridymite development during firing. The quartz initially present transforms into cristobalite starting at the grain edges. This dissolves in the calcium silicate liquid phase and precipitates as tridymite. During firing the amount of quartz present continually decreases, the amount of cristobalite initially increases and then later decreases, and the amount of tridymite continually increases.

(3) Glass Sand

For the manufacture of glass, silica sand of high purity is needed. Uniformity of grain size is important; glass sand should be between 20-mesh and 100-mesh size with a minimum of coarse or fines. The following table gives specifications for glass sand approved by the glass division of the American Ceramic Society and the Bureau of Standards:

	Min. <u>SiO_2 %</u>	Max. <u>Al_2O_3 %</u>	Max <u>Fe_2O_3 %</u>	Max. <u>$\text{CaO} + \text{MgO}$ %</u>
First quality optical glass	99.8	0.1	0.02	0.1
Second quality flint glass containers and tableware	98.5	0.5	0.35	.2
Third quality flint glass	96.0	4.0	0.35	.5

	Min. <u>SiO₂ %</u>	Max. <u>Al₂O₃ %</u>	Max. <u>Fe₂O₃ %</u>	Max. <u>CaO+MgO %</u>
Fourth quality, sheet glass, rolled, polished plate and window glass	98.5	.5	.06	.5
Fifth quality, sheet glass, rolled, polished plate and window glass	99.0	4.0	.06	.5
Sixth quality, green glass containers	99.0	0.5	.3	.5
Seventh quality, green glass	99.0	4.0	.3	.5
Eighth quality, Amber glass containers	98.0	.5	1.0	.5
Ninth quality, Amber glass	95.0	4.0	1.0	.5

Angular grains are preferred by some manufacturers owing to their larger surface area and more rapid reaction in the melt, but this feature does not appear a necessary requisite of good glass sand.

(4) Enamels

For enamel frits a good grade of fine glass sand is used. Iron content should be less than 0.2 percent; alumina less than 0.4 percent; and silica, over 97.5 percent.

(5) Pottery Flint

Finely ground silica is used for pottery flint in ceramic bodies. The chief requirements as to purity is that the iron content should be low when a white colour is desired.

(6) Sodium Silicate

Silica sand used in the manufacture of sodium silicate should be very pure. It should contain more than 99 percent silica; with not over 1 percent alumina; not over 0.5 percent lime and

magnesia combined; and less than 0.1 percent iron. Grain size is minus 20, plus 100 mesh.

(7) Paint Filler

Finely ground silica sand is used in the paint industry as a filler. For this use, white colour, fineness and freedom from impurities are the main requirements.

(8) Foundry Sands

For foundry sand a highly refractory tough silica sand having rounded grains with rough surfaces is preferred. The silica sands are bonded with clay and rough grain surfaces improve the bonding power. A sand with a rounded grain is preferred to angular grains owing to the increase in the permeability of the sand, which allows the escape of gases during casting. Grain size is usually between 20- and 200- mesh in closely sized ranges.

(9) Other Uses

Silica is also an ingredient in some fibre glass and rock wool and is used in cleansing and scouring powders, matches, fertilizer filler, roofing paper, sandblasting operations, and sawdust. Various grades of closely sized sand are used in water treatment plants as filtering media. Silica sand is also used in the manufacture of Portland cement which requires 13.6 percent SiO_2 .

Most consumers have very definite limits of tolerance for impurities. In the ceramic and glass industries, the percentage of iron oxide is important. If this is too high it may be possible to reduce the iron content to the permissible range by processes of beneficiation, such as air classification, washing

or acid leaching.

Moisture in delivered silica sand should not exceed 2.0 percent. A glass sand should all pass 20 mesh and not more than 3 percent should pass 30 mesh.

AGE OF THE SILICA SAND DEPOSITS IN THE MUSQUODOBOIT VALLEY

Except for a locality south of Elmsvale, where silica sand is exposed on the surface all the known deposits underlie a mantle of glacial drift and are evidently of pre-glacial age. The silica sand contains some lignitic material. Age determination on spores, pollen and wood of the lignite indicate the silica sand and clay deposits of the Musquodoboit Valley are Cretaceous in Age.

SILICA SAND DEPOSITS

1) Paint Brook Area

Drilling on the clay horizon at Paint Brook, near Centre Musquodoboit, intersected several zones of silica sand. All holes that intersected the entire thickness of clay encountered silica sand at its base. Hole 72 cut 29 feet of silica sand interbedded between two clay horizons and in hole 76, 19 feet of silica sand underlies the glacial drift and is on top of the clay. Other holes drilled outside of the clay horizon also intersected silica sand. From information available it is evident that extensive near surface deposits of silica sand occur in the Musquodoboit Valley. At Paint Brook more detailed drilling would be necessary to definitely prove tonnage and

quality for industrial uses.

The silica sand overlying and interbedded with the clay is white, angular and carries over 98 percent SiO_2 ; the silica sand underlying the clay is finer grained and holds some white and black micas. This material carries about 95 percent SiO_2 .

The following table gives the information on the silica sand deposits obtained from drilling and the meagre chemical data available of the raw material:

<u>Core No.</u>	<u>Footage</u>	<u>Percent SiO_2</u>	<u>Remarks</u>
17	23.0-43.0	94.10	Hole bottomed in silica sand
20	9.0-20.0	95.80	Hole bottomed in sand
30	20.0-55.0	95.10	Bottomed in silica sand
40	24.0-33.0	98.5	Silica sand on top of the clay
44	14.0-20.0	98.60	Silica on top of clay. Hole bottomed in silica sand
70	21.0-40.0	97.90	White quartz with some mica
	40.0-50.0	98.35	
	50.0-60.0	98.40	

The above samples were tested with a hand magnet.

floated in water and the silica content determined. The results

are as follows:

	51.0-60.0	99.04	
	60.0-70.0	98.81	
	70.0-80.0	98.82	
70	8.0-15.0	98.60	White angular quartz.
	15.0-25.0	97.13	

(2) Elmsvale Area

Silica sand occurs at several horizons in the Elmsvale area. Southwest of Elmsvale a large area of silica sand is exposed on surface. Drilling in the area indicates that silica sand occurs on top of the clay under a thin mantle of glacial drift and also underlies it.

The silica sand exposed southwest of Elmsvale is reddish to brownish in color due to iron staining. When left exposed to the weather it becomes white. Sieve analysis indicate this silica is unsuitable for foundry use as only 2 percent of the material passed through a 200 mesh sieve. The areal extent of the deposit is not known. A drill hole indicated a thickness of over 50 feet at the exposure.

Samples of silica sand were obtained by washing and using a chopping bit. There is no doubt considerable contamination of the silica sand with such a crude method of sampling. To obtain an uncontaminated sample it would be necessary to follow down the hole with casing to avoid contamination from the upper portion of the deposit. This procedure will be necessary to arrive at an average silica content of the raw material. Several of the holes were stopped after intersecting the clay horizon.

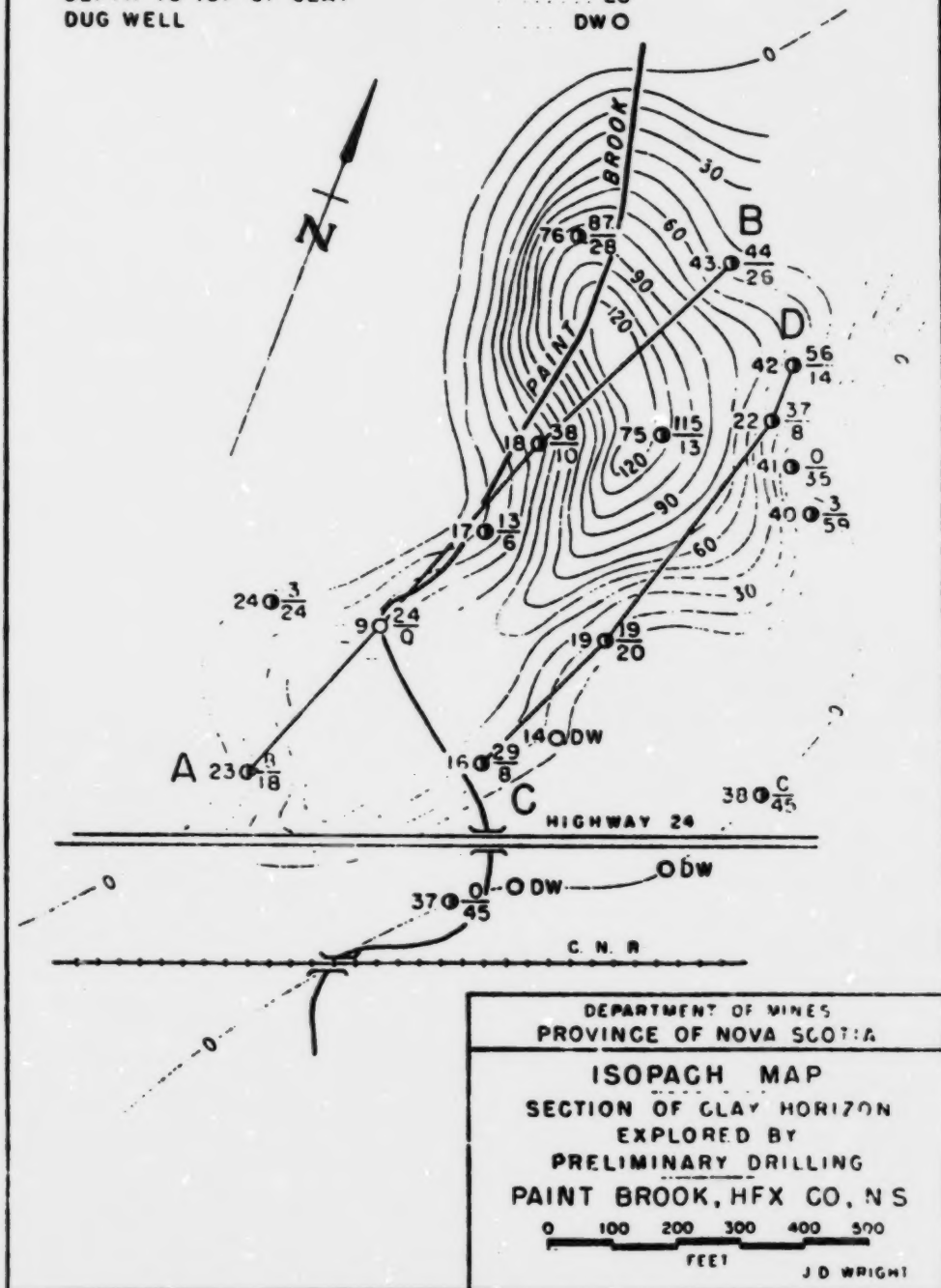
The data available on the silica deposits in the Elmsvale area are tabulated below. Plans showing the distribution of the silica sand are attached.

Hole No.	Footage	Percent SiO ₂	Remarks
29	14.0-35.0	90.98	Grey silica sand with micas.
32	30.0-35.0	97.99	Hole ended in silica sand. Depth unknown.
34	35.0-50.0	88.70	Ended in silica sand.
Surface exposure	0.0-6.0	93.15	This sample was washed through 14 mesh screen and +14 mesh fraction.
		96.67	Analyzed
81	3.0-21.0	98.20	White silica sand
	21.0-31.0	97.90	
82	64.0-67.0	98.10	White silica sand
	67.0-85.0	97.90	
83	0.0-6.0	96.67	
103	9.0-43.0	88.90	Contaminated from glacial drift
	43.0-53.0	92.89	
104	72.0-90.0	97.08	Hole bottomed in silica sand
	90.0-94.0	94.57	
105	30.5-34.0	98.00	Ended in silica sand
106	19.6-35	92.90	Unwashed
		95.95	Washed with water
	35.0-42	96.17	Unwashed
	35.0-42.0	97.32	Visible mica
107	60.0-65.0	96.18	
	65.0-73.0	96.33	
108	29.0-65.0	92.50	
109	20.0-30.0	94.00	
	30.0-35.0	89.00	

LEGEND

CONTOUR (INTERVAL 10 FEET)
 NUMBER OF HOLE
 POWER DRILL WITH SPLIT TUBE
 HAND SAMPLER
 THICKNESS OF CLAY
 DEPTH TO TOP OF CLAY
 DUG WELL

— 30 —
 43 ①
 ①
 ①
 87
 28
 DW ①



<u>Hole No.</u>	<u>Footage</u>	<u>Percent SiO₂</u>	<u>Remarks</u>
110	40.0-55.0	92.61	Silica under clay Depth unknown
111	49.0-60.0	93.68	Hole ended in silica sand
112	26.0-44	Not determined	Hole ended in silica sand
113	28.0-44.0	94.31	Hole ended in silica sand
114	74.0-81.0	Not determined	Hole ended in silica sand
115	93.0-100	Not determined	Hole ended in silica sand

(3) Stewart Property

Silica sand was collected from two drill holes

during investigation of the clay deposits.

<u>Hole No.</u>	<u>Footage</u>	<u>Percent SiO₂</u>	<u>Remarks</u>
64	26.0-56.0	96.10	White silica sand with mica. Hole bottomed in silica.
65	29.0-56.0	97.70	White silica sand. Hole bottomed in silica.

BENEFICATION OF THE STEWART SILICA SAND

Extensive deposits of unconsolidated silica sands occur in the Musquodoboit Valley. Drilling on the clay belts have indicated that silica sand underlies, is on top, and is interstratified with the clays. South of Elmsvale silica sand is exposed on the surface and at many points throughout the area it occurs under a thin covering of glacial drift. More drilling is necessary to define the areal extent of most of the silica horizons in the area.

Silica sand was intersected in most of the drill holes on the Stewart Property. Hole 64 intersected 40 feet (20.0-60.0') of micaceous silica, containing 96.10 percent SiO_2 . Hole 65 penetrated 27 feet (29.0-56.0') of silica sand carrying 97.75 percent SiO_2 . Both holes ended in silica sand.

The two samples were submitted to the Engineering Division of the Nova Scotia Technical College for beneficiation tests to determine if the mica can be removed economically and the silica content upgraded to meet specifications for industrial uses. A summary of the beneficiation tests as outlined in a report dated April 10, 1968, by Dr. George Aletan is as follows:

The mica in both samples is chiefly dark brown iron-bearing biotite, with minor amounts of muscovite.

The screen analysis of samples 64 and 65 are as

follows:

	Sample SP 64	Sample SP 65
-10 +14 mesh	1.5%	3.8%
-14 +20 mesh	4.5%	6.3%
-20 +28 mesh	11.6%	12.3%
-28 +35 mesh	21.4%	13.0%
-35 +48 mesh	27.9%	24.6%
-48 +60 mesh	24.6%	23.7%
-60 +80 mesh	5.5%	11.3%
	100.0%	100.0%

Elimination of mica from the samples was undertaken from the original sample by flotation without further grinding, as microscopic investigation revealed both types of mica as liberated at the above fineness of the silica sand.

Promotion and flotation of mica was achieved by Petroleum Sulfonate, a crude oil distillation product dissolved in kerosene to 10% or 20% solution. Coal Tar Creosote was used as a frother.

The results of flotation of both samples at 40 percent solids, 11 lb/ton petroleum sulfonate, 3-4 lbs./ton kerosene and 0.025 lb./ton Coal Tar Creosote were as follows:

Products	Sample 64		Sample 65	
	% Wt.	Insoluble	% Wt.	Insoluble
High Concentrate	3.3		3.26	
Silica Tails	96.7	95.05% (Av. 98.5)	96.74	98.38%
	<u>100.0</u>		<u>100.00</u>	
Head Sample	96.10% silica		97.70% silica	

It should be noted that flotation with Petroleum Sulphonate removed most of the dark brown-to-black iron-bearing biotite, but not the muscovite, which remained in the purified silica product. However, the high insoluble content of the purified product strongly indicates a silica product of high quality suitable for many industrial purposes. It is estimated the cost of the reagents to purify a ton of silica will not exceed 0.50 cents.

(4) Silica Sand at McNutt Brook

Silica sand was intersected in several of the drill holes during an investigation of a clay occurrence located in the bed of McNutt Brook. The area investigated is $2\frac{1}{2}$ miles north and slightly west of the village of Middle Masquodoboit and near Glenmore road.

Bedrock intersected in hole 47 indicated the area is underlain by rocks of the Windsor Group of Carboniferous Age. Glacial debris varies from 8 to 55 feet in thickness, thus indicating a very irregular erosion surface on the Windsor Group rocks.

The silica sand varies in color from white to reddish brown depending on the amount of iron present. No doubt most of the iron present in the upper portion of the silica sand deposit was derived from the overlying glacial till by the downward movement of surface waters.

The data available from samples tested for silica are tabulated below.

<u>Hole</u>	<u>Footage</u>	<u>Percent Silica</u>	<u>Remarks</u>
45	26.0-35.0	97.55	Hole bottomed in silica
46	15.0-40.0	96.98	" "
53	27.0-33.0		" "
54	45.0-54.0		" "
55	35.0-47.0	96.99	" "
57	38.0-43.0	71.50	" "
	43.0-60.0	98.50	" "

Much more information is required to properly assess the economic value of this deposit. Information at hand indicates the possibilities of this area as a source of silica sand. Complete chemical analysis is necessary to determine the impurities that are harmful for the utilization of the silica sand.

(5) Other Silica Deposits

<u>Location</u>	<u>Footage</u>	<u>Percent SiO₂</u>	<u>Remarks</u>
Aulton McKay Hole #1	40.0-100.0	81.50	Carbonaceous material. L.O.I. 1.47%
Fred Redden Property Hole #8	20.0-40.0 40.0-60.0	77.20 77.40	L.O.I. 1.27% L.O.I. 1.76% Silica sand high in mica and carbonaceous material
Fred Redden Property Hole #10	0.0-20.0 20.0-40.0	75.65 82.55	L.O.I. 1.95% L.O.I. 1.03%

CONCLUSIONS

None of the known silica sand deposits in the Muskegon-Valley have been explored sufficiently to define tonnage and silica content. Some of the sections intersected in drilling indicate a high grade silica sand; others would need beneficiation to upgrade the silica content for industrial uses. Tests completed indicate the silica content can be increased considerably by a water wash. Where the silica sand is beneficiated by washing, hydraulic classification is frequently used.

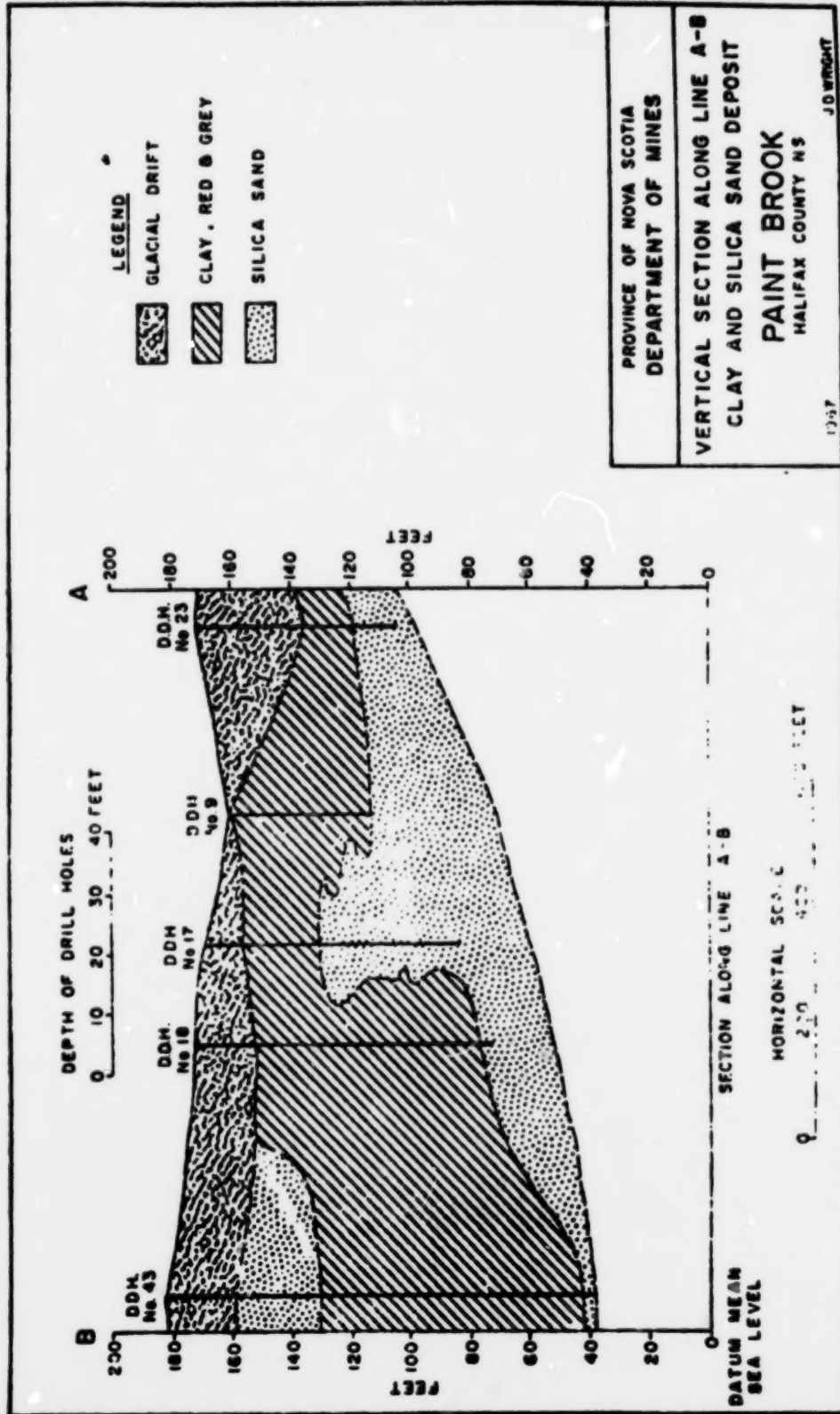
Removal of the iron oxides can be achieved by acid leaching.

Tests indicate the chief impurities in the silica sand are white and brown micas. Most of the biotite can be removed by promotion and flotation by petroleum sulfonate, a crude oil distillation product dissolved in kerosene to 10% or 20%. Coal tar Creosote was used as a frother. Cost of beneficiation is 0.40 cents per ton.

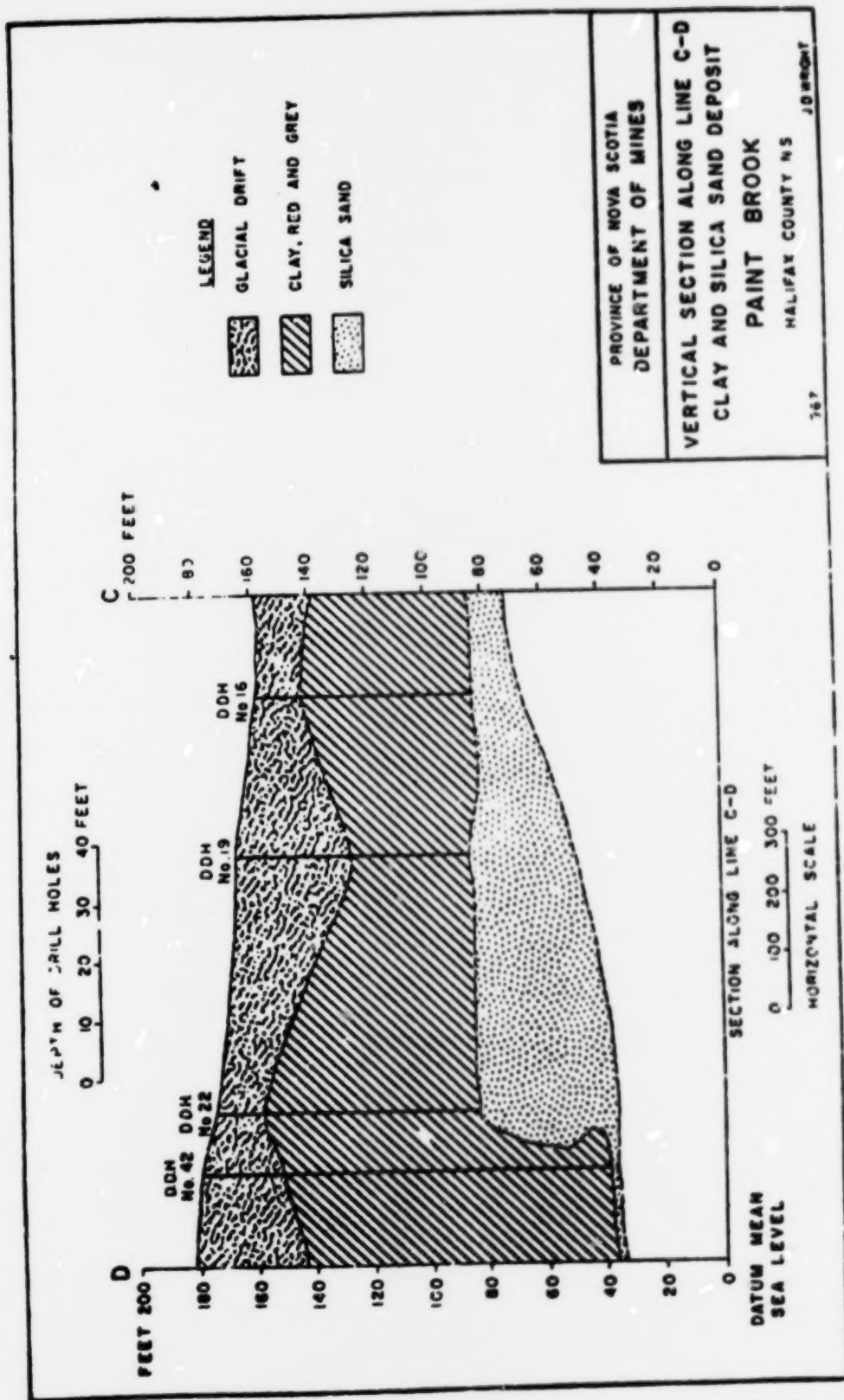
For commercial utilization specifications of silica sand may require that the following features be investigated:

- a. Mineralogy of the sand; what accessory minerals; what percentage of silica grains;
- b. Chemical purity, analyses of silica, alumina, iron, lime, magnesia and alkalis;
- c. Grain size, and sorting of the grain size (sieve analyses);
- d. Toughness of the grains;
- e. Roundness or angularity of the grains;
- f. Percentage of fines present.

At present, investigations are underway to determine many of the features listed above in order to arrive at a proper assessment of the economic potential of the silica sands deposits in the Marquette Valley for commercial utilization.

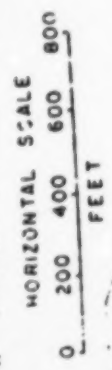


Transparency of map in OFR C90



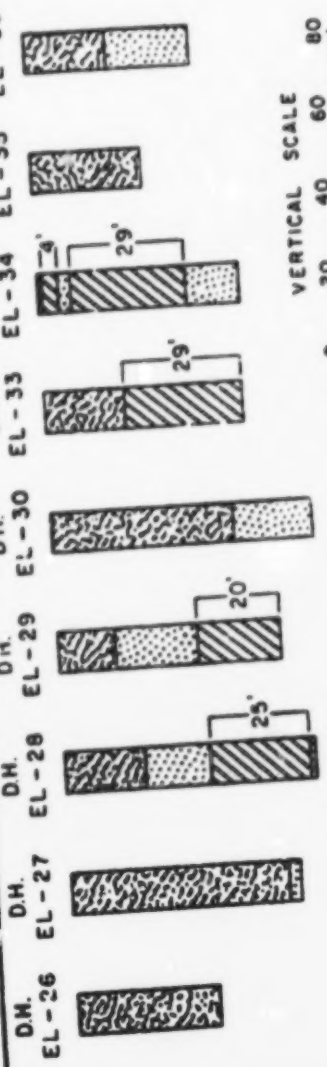
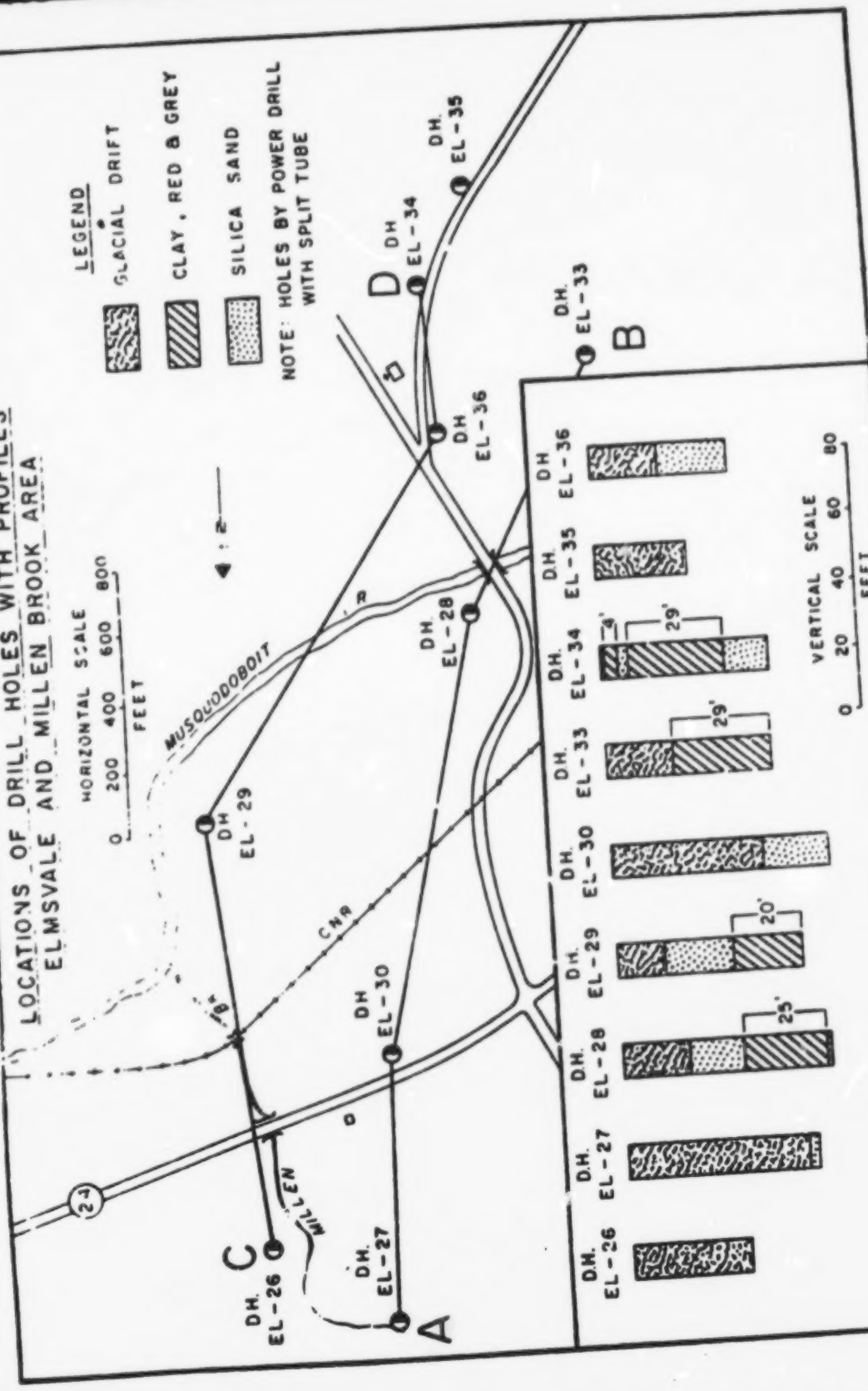
Transparency of map in OFR C90

LOCATIONS OF DRILL HOLES WITH PROFILES ELMSVALE AND MILLEN BROOK AREA

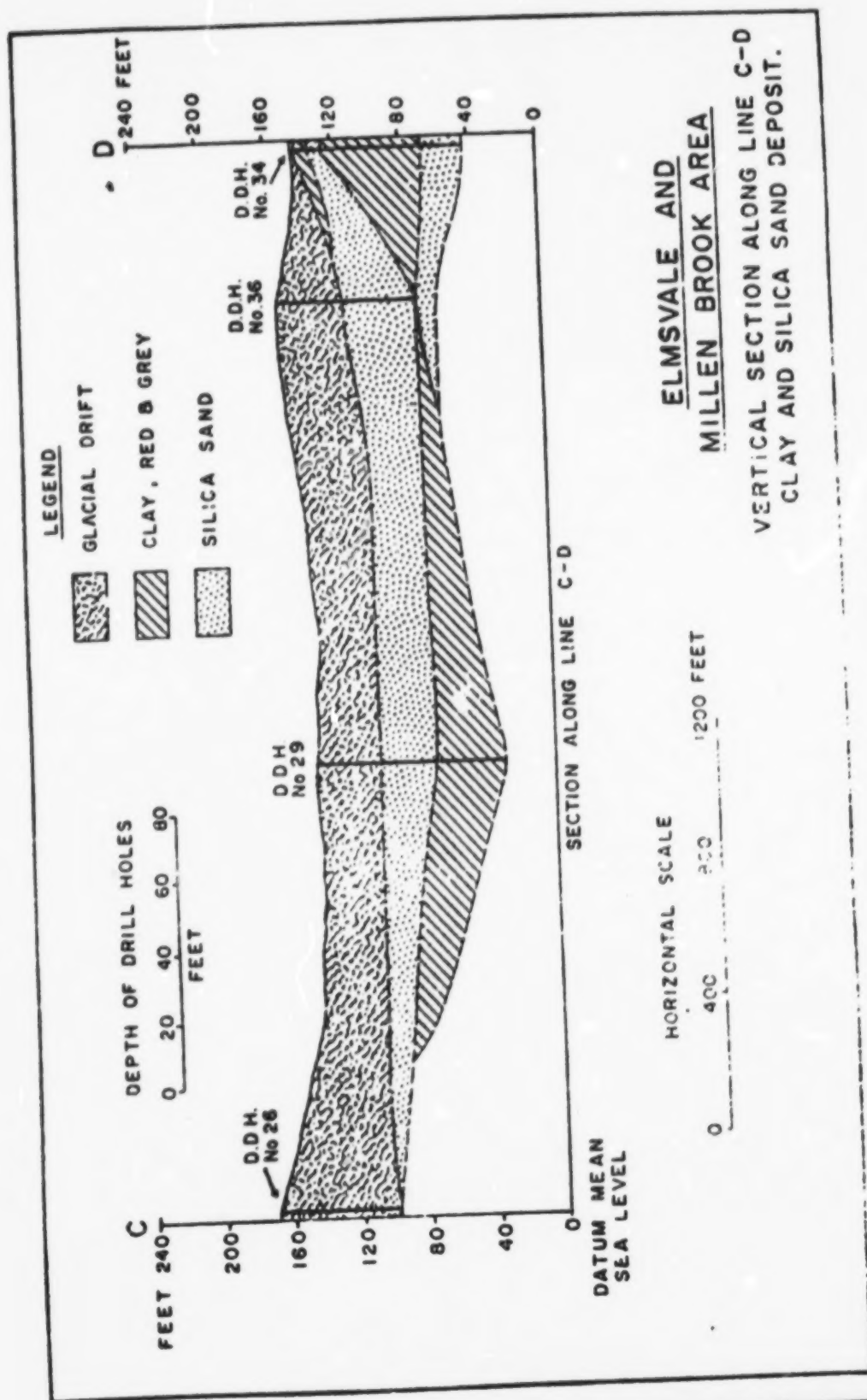


LEGEND

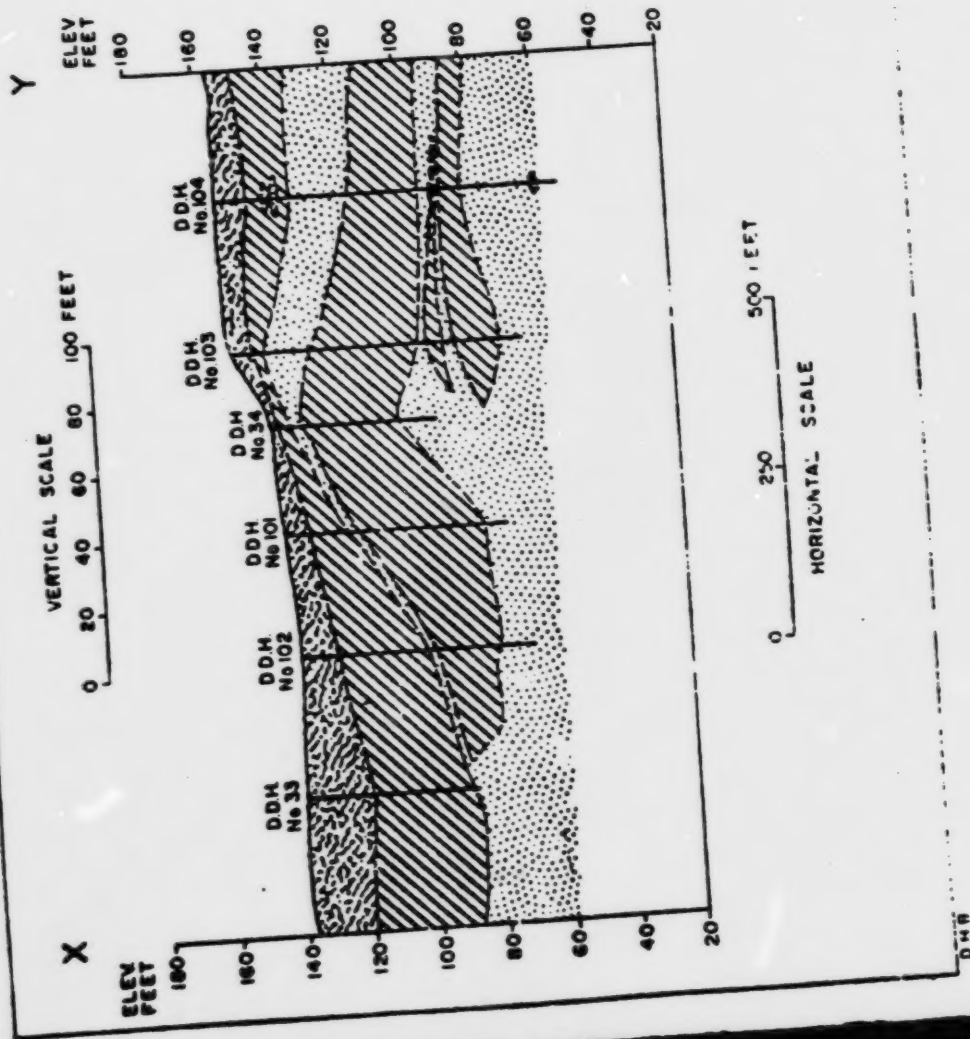
- GLACIAL DRIFT
- CLAY, RED & GREY
- SILICA SAND
- NOTE: HOLES BY POWER DRILL WITH SPLIT TUBE



Transparency of map in OFR 690



Transferred from map in O.R. 59C



PROVINCE OF NOVA SCOTIA
DEPARTMENT OF MINES

VERTICAL SECTION X-Y
CLAY AND SILICA SAND DEPOSIT

— ELMSVALE AREA —
HALIFAX COUNTY, N.S.

J.D. WRIGHT

1963



CLAY AND SAND DEPOSIT
at
ELMSVALE, HALIFAX COUNTY

by
John H. Fowler

1972

Geological Division
Department of Mines
Province of Nova Scotia

X-Ray Diffraction Analysis

The X-ray analysis was done by Dr. Yahya A. Majid of the Atlantic Industrial Research Institute, Nova Scotia Technical College. The methods he used were: the Hashimoto and Jackson's procedure and a procedure used at the College of Ceramics, Alfred University, New York.

"Hashimoto and Jackson's procedure depends, in principle, on the chemical purification of clays, by removing free alumina (Al_2O_3), free silica (SiO_2) and allophane. Iron oxide was removed by means of Dithionite - Citrate system buffered with sodium bicarbonate. The X-ray diffractograms for the solid crystalline residues were then obtained. In this method, clay minerals, non-clay residues and mixed-layer clay minerals were identified and estimated. The method used at the College of Ceramics, Alfred University, depends mainly on separating clays from non-clay minerals using the suspension technique. Clay minerals are then separated according to their size into fractions of -1 microns for morphology studies (using the Electron Microscope) and into fractions of -10 microns for the preparation of oriented samples for X-ray investigations."

The results of the X-ray analysis in table 3 show the Kaolin group of clay minerals present in relative abundance from medium to high in the samples tested with kaolinite as the prominent constituent of this group. Quartz, illite and montmorillonite are indicated in abundance ranging from low to medium. Hematite ranges from low to high and pyrite is present in one sample tested.

Table 3. X-Ray Diffraction Analysis of Some Elmsvale Clay Samples

Sample No.	Kaolin Group	Quartz	Illite	Montmorillonite	Mixed-Layer and Miscellaneous Constituents	Humite	Grade
EL 109 - 4	A	D	C	D	Pyrite (D)	D	Low Duty (P.C.E. 20)
EL 109 - 7							
EL 105 - 4	B	C	B	C	Illite - Mont. (D)	B	Low Duty (P.C.E. 23)
EL 109 - 11	B	B	B				Low Duty (P.C.E. 23)
EL 107 - 3							Medium Duty (P.C.E. 31)
EL 107 - 4	B	B	C	D			Medium Duty (P.C.E. 29)
EL 107 - 5							Medium Duty (P.C.E. 31½)
EL 81 - 1	B		D	D	Illite - Mont. (D)	A	High Duty (P.C.E. 31)
EL 81 - 2	B	B	C				High Duty (P.C.E. 32)
EL 82 - 1	A	B	C	C	Chlorite - Mont. - Illite	C	High Duty (P.C.E. 31½)
EL 105 - 2	B	C	C			C	High Duty (P.C.E. 31)
EL 105 - 3	B	C	C	D	Illite - Mont. (D)	A	High Duty (P.C.E. 31)
EL 105 - 5	B	C	C				High Duty (P.C.E. 32½)

Relative abundance of the minerals in the sample: A - High, B - Medium, C - Low, D - Very Low

BENEFICIATION OF CLAYS

Most of the clays of the Elmsvale deposit require beneficiation to improve grade. Mineral analyses show iron and quartz to be the most undesirable constituents. Magnetic separation of the iron with a laboratory-size Jones Magnetic Separator was tried by the Mineral Processing Division of the Department of Energy, Mines and Resources at Ottawa, however the results were disappointing. Iron removal by acid leaching and quartz removal by the "Beaker Decantation" method were done by Mr. Cyril Cole of the Laboratory for Investigation of Minerals, Nova Scotia Technical College in Halifax with the results of each technique as follows:

Removal of Iron by Acid Leaching

Although no samples from the Elmsvale deposit were leached with acid, this method of iron removal worked on samples from the Paint Brook deposit which has clays similar to those at Elmsvale. Acid leaching techniques applied to clay samples from Elmsvale would undoubtedly produce similar results.

The leaching techniques were: 1. Sample PB 75-10 was leached with boiling 19% HCl for time intervals of 3, 6, 9, 12 and 15 minutes. 2. Sample PB 22-1 and PB 22-2 (combined) was leached for 10 minutes with boiling HCl using concentrations of 2.5%, 5%, 10%, 15% and 20% and rechecked with concentrations of 2.5%, 5%, 7.5%, 10%, 15% and 20%. A combined 2500 gram sample (Sample 68-83) made up of portions of all clay samples from Paint Brook was leached with 10% boiling HCl for 10 minutes.

Acid leaching using boiling HCl produced three results: The percent of iron as Fe_2O_3 is reduced; the percent of Al_2O_3 is reduced and the pyrometric cone equivalent is increased. Two of these results are desirable (lowering or removal of the Fe_2O_3 content and the increased value of the pyrometric cone equivalent). Lowering of the Al_2O_3 content is undesirable, so optimum leaching conditions must be established for each clay. In test no. 1 (Table No. 4, Sample PB 75-10) leaching with boiling 19% HCl for a period of three minutes is optimum as longer periods of time only lower the percent of Al_2O_3 . Test no. 2 (Table No. 4) shows that optimum conditions are achieved with a percent concentration of HCl between 15 and 20 percent for a time interval of ten minutes. Test no. 3 (Table No. 4) done on the combined Paint Brook sample indicates that leaching with boiling 10% HCl for ten minutes produces a pyrometric cone equivalent of $31\frac{1}{2}$ up from 23-. This result is lower than that

Table 4. Results of Acid Leaching Tests

Test No. 1: Acid Leaching of Sample PB 24-10										
Chemical Analyses										
<u>SiO₂</u>	<u>Al₂O₃</u>	<u>Fe₂O₃</u>	<u>Mn₂O₄</u>	<u>MgO</u>	<u>CaO</u>	<u>Na₂O</u>	<u>K₂O</u>	<u>TiO₂</u>	<u>% Loss</u>	<u>Total</u>
43.90	34.55	7.19	0.02	0.48	0.47	0.64	0.14	0.44	11.02	99.10
Results After Leaching with Boiling 10% HCl										
	<u>Original Values</u>	<u>1 min.</u>	<u>5 min.</u>	<u>9 min.</u>	<u>15 min.</u>	<u>25 min.</u>				
% Iron as Fe ₂ O ₃ in Clay	7.19	0.25	0.25	0.25	0.25	0.25				
% Al ₂ O ₃ in Clay	34.55	30.59	28.67	27.83	25.14	22.64				
P. C. %	26	33-34	33-34	33-34	33-34	33-34				

Test No. 2: Acid Leaching of Sample PB 22-1 and PB 22-2 (Combined)											
Chemical Analyses											
<u>SiO₂</u>	<u>Al₂O₃</u>	<u>Fe₂O₃</u>	<u>Mn₂O₄</u>	<u>MgO</u>	<u>CaO</u>	<u>Na₂O</u>	<u>K₂O</u>	<u>TiO₂</u>	<u>% Loss</u>	<u>Total</u>	
45.37	34.80	4.52	0.02	0.44	0.55	0.15	0.11	0.76	11.84	99.67	
Results After Leaching with Boiling HCl for 2 Minutes											
	<u>Original Values</u>	<u>% Concentration of HCl</u>									
		<u>2.5</u>	<u>5</u>	<u>10</u>	<u>15</u>	<u>20</u>					
% Iron as Fe ₂ O ₃ in Clay	4.52	.71	1.24	0.68	0.44	0.10					
% Al ₂ O ₃ in Clay	34.80	61	33.84	34.27	34.14	33.74					
P. C. %	31-	2-	33-	33-34	33-34	34-					
Checked Results											
	<u>Original Values</u>	<u>% Concentration of HCl</u>									
		<u>5</u>	<u>5</u>	<u>7.5</u>	<u>10</u>	<u>15</u>	<u>20</u>				
% Iron as Fe ₂ O ₃ in Clay	4.52	.79	1.19	0.72	0.47	0.17	0.17				
% Al ₂ O ₃ in Clay	34.80	52	34.20	34.05	33.78	33.60	33.30				
P. C. %	31-	11-	32-	33-34	33-34	33-34	34-				

Test No. 3: Acid Leaching of Sample 68-83 (combined Material of all Paint Brook Clay Samples)											
Chemical Analyses											
<u>SiO₂</u>	<u>Al₂O₃</u>	<u>Fe₂O₃</u>	<u>Mn₂O₄</u>	<u>MgO</u>	<u>CaO</u>	<u>Na₂O</u>	<u>K₂O</u>	<u>TiO₂</u>	<u>% Loss</u>	<u>Total</u>	
53.80	29.01	4.83	0.02	0.31	0.43	0.06	0.14	0.55	10.30	99.40	
Results After Leaching for 10 minutes with Boiling 10% HCl											
	<u>Original Values</u>	<u>After Leaching</u>									
% Iron as Fe ₂ O ₃ in Clay	4.83	0.17									
% Al ₂ O ₃ in Clay	29.01	28.46									
P. C. %	23-	31+									

obtained for samples in test no. 1 and test no. 2, however it is probably an optimum value because initially the sample (Lab. No. 68-83) contains a fairly high percent of silica (53.80%) and a lower percent of alumina (29 %).

Table no. 5 shows the unfired and fired properties of the combined Paint Brook sample. Sample lab. no. 68-83 had briquettes made by hand using brass moulds. Sample lab. no. 68-84 had briquettes made of the same material but formed with a de-airing and extrusion apparatus and sample lab. no. 68-85 was composed of the same material as lab. no. 68-83 and lab. no. 68-84 but was leached with 10% HCl for a period of 10 minutes. Samples 68-83 and 68-84 have a P.C.E. value of 23- while sample 68-85 leached in HCl attained a P.C.E. of $31\frac{1}{2}$.

Removal of Free Quartz

The procedure used was a "Beaker Decantation" method described in "Purpose in Fine Sizing and Comparison of Methods", a paper by E. J. Pryor, H. N. Blyth and A. Eldridge, presented at the Institution of Mining and Metallurgy Symposium on Recent Developments in Mineral Dressing in London, 1952, and published by the I.M.M., 1953. Some modifications were made in this procedure with such being presented in "Removal of Free Quartz from Musquodoboit Clays and its Effects on the Properties" by Cyril Cole, Laboratory for Investigation of Minerals, Nova Scotia Technical College, October, 1969. The size fraction obtained from the decantation were +30 microns, -30+20 microns, -20+10 microns, -10+6 microns and -6 microns. In some tests "waste -6 microns" was obtained.

Table 5. Unfired and Fired Characteristics of Combined Paint Brook Samples

Sample Number	Unfired Characteristics	D.F.E.	Fired Characteristics					Remarks
			° F	Fired Shrinkage %	Absorption %	Colour	Hardness	
Paint Brook combined sample (Lab no. AB-83) combined all samples from Paint Brook. 120 grams for each foot of sample to obtain properties of the clay body as on sample. Briquettes formed using molds.	Workability very good. Very plastic and smooth working. Water of plasticity 25.2%. Cracks with rapid drying at 85°C. Clay was rose brown after mixing the combined samples. Air shrinkage 4.25	23-	1790	1.15	19.44	lt. pinkish brown	Very Hard	Suitable for low duty refractories, artware, face brick and filling.
			1870	2.48	17.31	"	"	
			1930	4.57	13.69	"	Steel Hard	
			1980	5.32	11.67	lt buffish brown	"	
			2040	5.70	10.89	"	"	
			2090	5.94	10.06	"	"	
			2135	6.17	9.08	"	"	
			2190	6.73	8.03	"	"	
			2230	7.26	6.67	"	"	
			2275	7.70	4.85	lt yellowish brown	"	
			2315	7.71	3.70	"	"	
			2340	8.47	2.86	"	"	
			2365	8.89	2.07	yellowish brown to olive brown	"	
			2390	9.76	1.86	"	"	
			2405	8.85	1.91	"	"	
			2420	8.89	1.40	"	"	
Paint Brook combined Sample (Lab no. AB-84) briquettes formed with a de-airing and extrusion apparatus.	Same as (Lab no. AB-83) PB combined. Air shrinkage 5.0%. Safe drying at 85°C. Very good extrudability.	23-	1810	1.88	18.32	lt pinkish brown	very hard	Same as PB combined (Lab no. AB-83)
			1890	3.95	15.38	"	"	
			1940	5.82	11.80	lt buffish brown	Steel hard	
			2010	6.49	10.09	"	"	
			2060	7.13	9.16	"	"	
			2110	7.49	8.40	"	"	
			2155	8.10	7.32	"	"	
			2200	8.50	5.86	"	"	
			2230	9.18	5.15	"	"	
			2270	9.78	3.35	lt yellowish brown	"	
			2300	10.67	2.58	"	"	
			2330	11.02	2.07	yellowish br to olive br	"	
			2345	11.04	1.75	"	"	
			2380	11.70	1.58	"	"	
			2400	11.25	1.75	"	"	
Paint Brook combined sample (Lab no. AB-85) leached with boiling 10% HCl for 10 min	Workability good. Very plastic and smooth. Water of plasticity 8.47. Safe drying at 850°C. Air shrinkage 1.47. After leaching the clay was a light grayish buff.	31+	1820	0.74	22.24	white	very hard	Suitable for high duty refractories
			1970	1.81	20.51	"	"	
			1975	3.39	17.59	"	"	
			2035	4.87	14.65	creamy wh	steel hard	
			2095	5.29	13.24	"	"	
			2145	5.87	12.28	"	"	
			2185	6.41	11.73	"	"	
			2235	7.01	10.13	"	"	
			2275	7.41	8.89	"	"	
			2310	7.73	7.91	cream	"	
			2345	8.19	6.20	"	"	
			2385	8.68	5.35	"	"	
			2405	8.47	4.67	"	"	
			2435	8.54	3.98	"	"	
			2455	8.97	3.44	"	"	

Table 6. Percent of Size Fractions Obtained by Decantation

Sample No.	SPP Added	+100	+325	+30-200	+30-325	+20-30	+10-20	+6-10	-6	-6 Waste	Total	Losses
1134-1	Yes	20.7	---	13.8	---	5.6	4.5	3.5	46.4	3.6	98.1	1.9
1181-3	No	---	12.3	---	1.8	in +30-325	4.1	+10-20	78.7	---	96.9	3.1
1191-3	Yes	---	12.9	---	0.6	1.5	3.2	3.2	74.8	---	95.6	4.4
11104-4	No	---	5.7	---	0.8	1.1	1.4	1.3	84.0	---	94.3	5.7
11104-4	Yes	3.3	---	3.5	---	2.4	1.9	2.0	78.0	6.5	97.6	2.4
11107-3	Yes	1.7	---	8.5	---	2.7	7.1	4.5	60.0	11.0	95.5	4.5
11107-5	Yes	3.4	---	8.5	---	3.9	6.5	6.9	51.3	12.2	92.7	6.3

*SPP - Sodium Pyrophosphate

Differential thermal analysis tests were done on the +10-20, +6-10, -6, -6 waste size fractions (table 7). Pyrometric cone equivalent tests (P.C.E.) were done on the -6 micron, -6 micron waste and +6-10 micron and compared with the original P.C.E. (table 8).

D T A show the -6 micron material to have the least quartz while the P.C.E. value of the -6 micron fraction of each sample is the highest suggesting that the removal of quartz will increase the refractory grade of the clay. The adherence of clay particles to quartz particles requires the use of a wetting agent such as sodium pyrophosphate for dispersion, also after settling a large area is required to thicken the pulp which may be somewhat alleviated by the use of flocculents such as hydrochloric acid.

Table 7. DTA Analysis of Four Size Fractions After Decantation

Sample No.	SPP Added	D T A				
		+20-30	+10-20	+6-10	-6	-6 Waste
EL34-1	Yes	---	Q+K	Q+K	K	K
EL81-3	No	K+Q	K+Q	K+Q	K+ 5%Q	---
EL81-3	Yes	---	K+Q	K+ 5%Q	K+ 5%Q	K+ 5%Q
EL104-4	No	Q+K	Q+K	Q+K	K+trQ	---
EL104-4	Yes	---	Q+K	Q+K	K	K
EL107-3	Yes	---	Q+K	K+Q	K	K+trQ
EL107-3	Yes	---	Q	Q	K	K+trQ

Q - Quartz, K - Kaolinite, SPP - Sodium Pyrophosphate

Predominant mineral is listed first and percent quartz is approximate

Table 8. Comparison of P.C.E. Values

Sample No.	Colour	*SPP Added	P.C.E. Values			
			Original	-6M	-6M Waste	+6-10M
EL34-1	Very Lt. Buff	Yes	26+	32-	31+	20+
EL81-3	Grey	No	29	31½-32	--	--
EL81-3	Grey	Yes	29	33+	--	33
EL104-4	Brownish	No	31-31½	32½	--	--
EL104-4	Brownish Grey	Yes	31-31½	33+	33-	29
EL107-3	Grey	Yes	31½	34	32-32½	23-
EL107-5	Grey	Yes	31-31½	34+	32-32½	--

*SPP - Sodium Pyrophosphate

SILICA SAND AT EIMSVALE

Silica sand occurs overlying and interstratified with the Elmsvale clays. All sands which were intersected by the drill sampling program were assayed for silica content. Beneficiation tests were done on some of these sand samples by Mr. M.A.K. Grice of the Laboratory for Investigation of Minerals, Nova Scotia Technical College, Halifax, Nova Scotia with the tests and results contained in the Report "Silica Sand Deposits of the Musquodoboit Valley, Halifax County and Specifications and Uses of Silica Sand" by Dr. J. D. Wright.

Table 9. Specifications for Glass Sand

QUALITY	USES	CHEMICAL CONSTITUENTS			
		SiO ₂ (Min.)	Fe ₂ O ₃ (Max.)	Al ₂ O ₃ (Max.)	CaO MgO (Max.)
1st	- Optical Glass	99.8	0.020	0.1	0.1
2nd	- Flint Glass Containers	98.5	0.035	0.5	0.2
3rd	- Flint Glass	95.0	0.035	4.0	0.5
4th	- Sheet Glass, rolled and Polished Plate	98.5	0.060	0.5	0.5
5th	- Rolled and Polished Plate	95.0	0.060	4.0	0.5
6th	- Green Glass Container, Window Glass	98.0	0.300	0.5	0.5
7th	- Green Glass	95.0	0.300	4.0	0.5
8th	- Amber Glass	98.0	1.000	0.5	0.5
9th	- Amber Glass	95.0	1.000	4.0	0.5

Limits Recommended by U.S. Bureau of Standards

The following is an outline of the work done by Mr. Grice: Sand samples from nine drill holes were combined to determine what grade of silica could be produced from the Elmsvale sands. Samples E.L. 83-1, E.L. 104-4, E.L. 106-1, E.L. 106-6, E.L. 109-1, E.L. 109-2, E.L. 110-2, E.L. 111-3, E.L. 113-3, E.L. 115-2, E.L. 117-2, E.L. 117-3, E.L. 117-4, and E.L. 117-5 were combined for testing. A washing test and a magnetic separation test were done on the sands. In the washing test, 2000 grams of sand was washed several times in a Denver Flotation Cell. The sample was then drained and dried in the oven. A settling test was done on the "washings", then they were wet screened on a 200 mesh screen and the products dried in the oven. After drying, the sand and the +200 mesh washings were dry screened. Large amounts of mica were visible in the +200 mesh washings.

Table 10. Products Obtained by Washing and Screening

	Weight		Analyses %			Distribution %		
	Grams	%	SiO ₂	Fe	Al ₂ O ₃	SiO ₂	Fe	Al ₂ O ₃
Head Sample	1942	100.0	-	-	-	-	-	-
Washed Sand	1472	75.8	98.1	0.76	0.57	78.4	40.6	22.6
Washings +200 Mesh	262	13.5	97.6	0.90	0.89	13.9	8.5	6.2
Washings -200 Mesh	208	10.7	68.4	6.80	12.80	7.7	50.9	71.2
Head Calc.	-	-	94.8	1.43	1.92	100.0	100.0	100.0

Table 11. Size Analysis and Assays of Products

<u>Washed Sand Fraction After Magnetic Separation</u>				
Mesh	Assay			
	% Weight	SiO ₂	Fe	Al ₂ O ₃
+14	13.4	98.4	0.66	0.45
-14+28	34.1	98.6	0.69	0.40
-28+48	35.6	98.3	0.65	0.30
-48+100	11.4	98.5	0.69	0.35
-100+200	4.9	97.4	0.75	0.69
-200	0.6	84.5	4.50	4.30
<u>"Washings"</u>				
Mesh	Assay			
	% Weight	SiO ₂	Fe	Al ₂ O ₃
+48	3.0			
-48+100	28.7	97.6	0.90	0.89
-100+200	24.0			
-200	44.3	68.4	6.80	12.80
<u>Washed Sand</u>				
Loss On Ignition		CaO	MgO	
0.1		0.18	0.10	

Each size fraction from the screening was passed through the Carpco Dry Magnetic Separator running at 50 r.p.m. speed and a magnetizing current of 2½ amps.

Table 12. Results of Dry Magnetic Separation

Mesh Size	% Weight Magnetic Concentration
+14	Nil
-14+28	0.6
-28+48	1.1
-48+100	3.5
-100+200	4.2
-200	Insufficient sample for test

The amounts of magnetic concentrate from each test of Table 12 were combined for a chemical analysis.

% SiO₂

66.1

% Fe

14.0

Total magnetic concentration was 1.2% of washed sand so the magnetic separation would reduce the iron content by 0.16%.

Table 13. Comparison of Elmsvale Sand and Recommended Specifications

Mesh	Recommended	Average Glass Sand	Elmsvale Sand	
			As Washed	#20 Mesh Removed
+20	0	0.2	28.1	0.0
-20+35	40-60	14.4	38.1	52.9
-35+60	30-40	45.6	23.3	32.4
-60+100	10-20	32.2	5.0	7.0
-100	0.5	7.6	5.5	7.6

Results of Tests

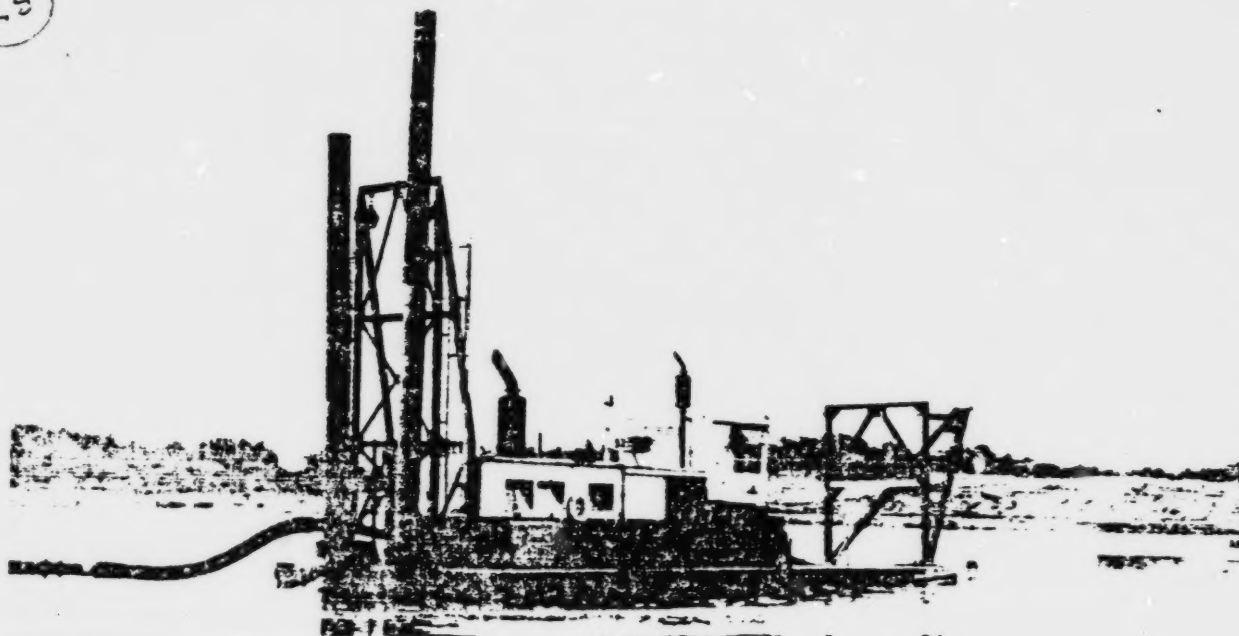
An eighth grade glass (amber glass) can be produced from the Elmsvale sand by washing and screening beneficiation, producing a sand product of 98%+ silica, however the Fe_2O_3 content is slightly exceeding the maximum at 1.08 per cent. Magnetic separation will improve the quality slightly (magnetic separation reduced the iron content by 0.16 per cent). In conclusion Mr. Grice states: "If any regional glass company could be interested in the possibility of using this sand, a sufficient quantity should be run through the N.S.T.C. Pilot Plant to allow customer evaluation and acceptance tests to be carried out."

SUMMARY OF DRILLING

Drilling was done at several locations in the Musquodoboit Valley in search for clay. One hundred and eighteen holes were drilled mostly on the clay deposits. Several holes were drilled however in areas where clay was suspected or indicated on the surface. Clay interstratified with sand, and of sufficient extent to be of economic interest was outlined at four locations, these indicated as location A, B, C and D on figure 7. Intersection of sand, limestone, gypsum, shale and gypsum and glacial till are also indicated.

The deposit at Elmsvale (location A) is the largest and contains the highest grade refractory clays. Drilling to the south and southwest beyond hole EL 81, EL 118, EL 105 and EL 82 would probably extend the deposit. Drilling to increased depths between the deposit at Elmsvale and the one at Paint Brook (location B) would probably show the two deposits as now indicated are in effect joined.

Generally the Paint Brook deposit has clays of lower P.C.E. values and higher iron content than those at Elmsvale. The Paint Brook clays are



Dredging operations at Pennsylvania Glass Sand's Millville site

GLASS SAND PRODUCTION

Practice in the USA and Britain compared

by A. Littler, BSc, MIQ

The author was the recipient of the 1981 Institute of Quarrying Nordberg Travelling Scholarship, which he used to make a two-week study tour of silica sand operations in the USA, comparing conditions and practice there with those in Britain in terms of the geology of the deposits and the extractive and processing methods.

Sand for glassmaking is often included under the general grouping of 'industrial sands', ie those naturally occurring sands or sandstones used for purposes other than construction. The other fundamental end-use for industrial sand is foundry moulding. Apart from this, silica especially when finely ground is used in many applications, notably ceramics and fillers.

Glass sand as supplied is a fine-grained, almost pure quartz material, usually rounded to a sub-angular rather than angular. A specification will normally demand a minimum of 99.5% silica (SiO_2) and a total iron oxide (Fe_2O_3) level of below 0.040%. Higher iron levels can be tolerated for the production of green or brown container glass and for flat glass manufacture. In all glass sand the presence of heavy or refractory minerals (heavy minerals being defined by having a specific gravity of above 2.9) is deleterious, tending to cause dark specks, irregularities or weak points in the glass. Alumina content can be much more variable, up to 2% for container glass and more in some circumstances.

Gradings normally demand almost nothing outside the

100 μ to 500 μ range. Large grains require more energy to melt and small grains tend to be lost in the furnace flue. Silica sand accounts for 70% of a typical glass melt.

GEOLOGY OF SOURCES

In the UK almost all sand for making clear containers (flint glass) is won from two distinct geological formations. First, the Cretaceous Lower Greensand exploited at Kings' Lynn and in the Reigate-Redhill area and secondly, the Carboniferous Millstone Grit worked at Oakamoor, Staffs, and in the Devilla Forest near Alloa. There are three other important locations: Chelford, Cheshire, where unconsolidated Pleistocene deposits are a major source of sand for flat glass manufacture; Messingham, Lincs, where recent aeolian sands are dug for amber glass production, and Loch Aline in Morven, Scotland, where a pure white Upper Cretaceous sandstone is mined by a pillar-and-stall technique. At Loch Aline the deposit is of such purity that it can be upgraded to a sufficiently low iron content for the manufacture of tableware glass.

Thus the UK is relatively rich in glass sand from several geological horizons. However, deposits of easily upgradable sand are fast running out and the silica sand industry finds itself in the familiar situation of locating suitable reserves in a competing land-use situation. Total production of glass sand was 2.2 million tonnes in 1975 and the industry must be regarded as a significant producer.¹

As might be expected, the US situation differs chiefly in scale. Production there is approximately 15 million tonnes a year, although figures are not as readily available as in this

¹The author is Reigate operations manager, Buckland Sand & Silica Co. Ltd.



Monitoring at the face at the Ottawa silica quarry

country. Glass sand (often referred to as melting sand) is produced in 25 of the 48 states. As the product is of such comparatively low value, the delivery element of its market cost is crucial. It is logical, therefore, to expect a wide distribution of producers either prepared to stand the cost of upgrading to specification a sand local to the market or able to sell a lower-grade product due to the uncompetitiveness of a superior material a considerable distance away. This is classically illustrated in the US where sources of really high-grade (ie fine, low iron, low heavy mineral, pure silica sands or sandstone) are won primarily from three main formations:

By far and away the most important source of melting sand is the Ordovician St Peter sandstone. This formation outcrops over 300,000 square miles in a broad north-south belt from Canada to Missouri². It is a fine semi-indurated saccharoidal sandstone often containing a total ferric oxide content (Fe_2O_3) of less than 0.030% with an almost insignificant heavy mineral suite apart from some epigenetic pyrite at the top of the formation. It is worked most extensively at Ottawa, Illinois, the justifiably self-named 'industrial sand capital of the world'. The Devonian Oriskany sandstone worked in West Virginia is of similar quality and these two formations supply 30–35% of US melting sand needs.

The next most important source is the unconsolidated glacial sands of southern New Jersey, accounting for 10–15% of nationwide production. Iron levels are slightly higher than in the St Peter sandstone and refractory minerals, notably sillimanite and kyanite, have to be dealt with. Other major sources of melting sand are the Cretaceous and recent sands of South Carolina, the feldspathic Wilcox Group in Texas and the feldspathic Eocene sands of California. All of these require a more sophisticated beneficiation process to remove iron oxide and heavy minerals and in some cases markedly to reduce alumina levels.

EXTRACTION METHODS

Large-scale American quarrying methods are innovative and cost-effective. A long-term reserve of uniform petrological character enables management to employ a specific mining method based on capital equipment requiring high initial cost but resulting ultimately in low running costs and manning requirements. In touring seven major silica operations

the writer witnessed five entirely different winning techniques, only one of which was based on conventional load-and-haul equipment. Four methods unusual to British operators are described below.

Heading blasting

Heading blasts are no longer practised in the UK on safety grounds. At the Pennsylvania Glass Sand Company's Berkeley Springs operation it is employed on a massive scale, up to 300,000 tons (US) being brought down by 50 tons of ANFO prills stacked in a 5ft x 5ft heading. The crudely shot rock is loaded by a Dart 15yd³ front-end loader into 110 ton Dart dumptrucks. The quarry is a textbook 'notch' working, the Oriskany sandstone dipping at 50° between black shales above and limestone below.

Monitoring

Hydraulic mining (or monitoring) is practised in the St Peter sandstone around Ottawa, Illinois. Here the 90ft face is drilled and crudely blasted to bring down a slumped pile of shot rock. This is then broken up and slurried by the action of 250 lb/in² water jets. The operator of the water cannon, or monitor, assists the flow of sand slurry into a sump from which it is drawn by a venturi-induced vacuum in a continuously pumped water pipeline. The white sand slurry is normally scalped on the quarry floor before pumping to the washing plant. Two companies, Ottawa Silica and Martin Marietta, employ the same method within a few miles of each other. Both are capable of outputs of 1.5 million tons produced primarily by two double-shifted monitors. Monitoring is ideal in this location as the deposit is weakly indurated and of consistent grading and geochemistry, notably with Fe_2O_3 levels which are almost always less than 0.030% after washing.

Dredging

In New Jersey the Pennsylvania Glass Sand Company are working a 30ft thick unconsolidated glacial sand using barge-mounted dredge pumps. In this case the workings border the wetlands of the Delaware estuary and the water table is penetrated almost immediately. The unconsolidated nature of the deposit, the onerous task of constantly dewatering a working area and the long distance from working

face to plant all combine to make wet working the obvious extraction method. Again, however, the geochemistry is critical: if iron and/or heavy mineral contents were severely variable, then the impracticability of selecting feed with a dredge head would cause fluctuations in the non-silica element of the final product or would necessitate a processing plant constantly geared to upgrade the poorest quality head material.

The pontoon-mounted 16in dredge pumps are capable of handling 600 tons/h up to 2,000ft, assuming no head. The dredge pipe can employ a cutting head or a jetting pipe: both or neither are used according to the compaction of the material. The pontoon pivots on steel rams raised or lowered hydraulically. The dredger pipe can be lowered vertically or at an angle of up to 45°. In practice dredging is carried out in a broad arc around the barge to a depth of 25ft. If it is economic to dredge below these depths, then the water level in that area is first artificially lowered. The slurry is relay-pumped every 2,800ft, and eventually distances of up to 5 miles will be pumped. The repeated pumping is useful in breaking down clays and agglomerates and in removing some of the iron-rich surface coatings from the sand grains.

Motor scraper

The unconsolidated Eocene feldspathic sands of California are eminently unsuitable for wet working. Generally speaking, Californian operators have to purchase large volumes of water for sand washing and regulations governing effluent disposal are very strict. These deposits are worked by motor scraper, both at Martin Marietta's Byron works and at Ottawa Silica, Oceanside. At Byron a total annual production of nearly half a million tons is mined by a Cat 633D motor scraper on two shifts. The scraper works across the strike of strata dipping at 40–50°. As there is considerable variation in iron oxide and alumina levels from bed to bed this method has been found to be crudely effective in smoothing the geochemistry of the deposit. The 633D picks up 30yd³ and cycles every 7min, delivering 250–300 tons/h to the plant. The scraper discharges over a grid into a hopper directly feeding a conveyor to the plant. This single-machine quarrying operation appeared most economic, and the quarry itself was very tidy as a consequence.

British operators usually dry-work glass sand in order to mine selectively. Rope faceshovels, draglines and hydraulic backacters are normally used, while wheel loaders load and carry to conveyors in soft deposits. In Millstone Grit quarries, a conventional drill/blast/load/haul method is used.

SAND BENEFICIATION

Crushing and screening plant in the US and the UK are essentially similar. For final comminution to individual sand grains, wet rod and ball mills are used. Once reduced to sand size, almost all silica sand beneficiation processes prior to drying, dry grading or dry grinding require copious quantities of cheap clean neutral water.

Wet processing methods

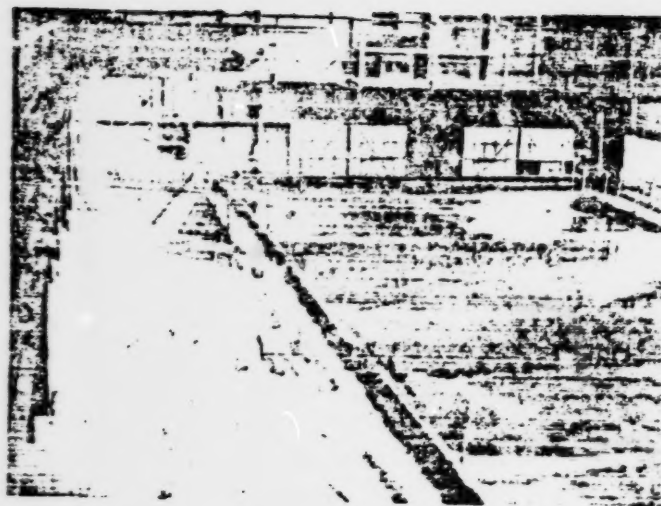
Upgrading sand to a glassmaking material involves a series of processes with up to five main objectives:

- 1 Removal of +500µ oversize
- 2 Removal of -100µ slimes
- 3 Reduction of Fe₂O₃ content
- 4 Removal of heavy minerals
- 5 Reduction of alumina content.

Objectives 1 and 2 always apply; 3 and 4 normally do unless the deposit is exceptionally pure as in some locations in the St Peter and Oriskany sandstones. Objective 5 sometimes applies but is very much dependent of the type of glass to be produced.

Removal of unwanted size ranges

Oversize removal can be carried out on water-jetted vibrating wedgewire screens or occasionally, as by Ottawa Silica,



Processed silica settling out at the Wedon plant of Martin Marietta

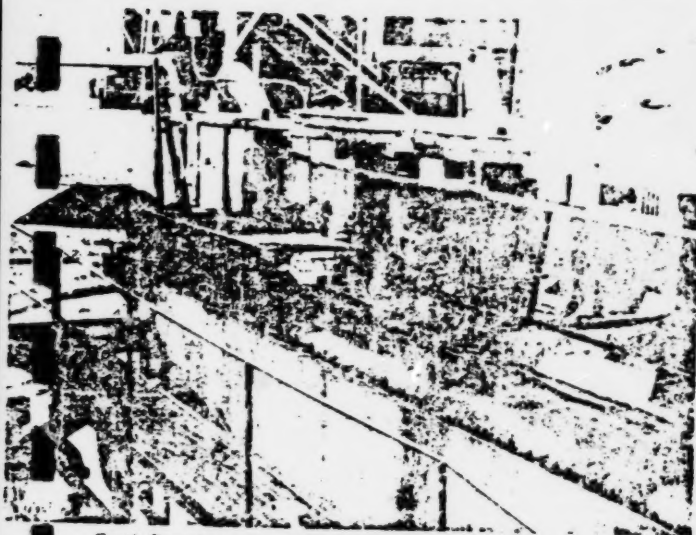
Ottawa, Illinois, by static DSM sieve bends where the amount of oversize is fairly minimal. Methods are essentially similar on both sides of the Atlantic.

Silt removal, on the other hand, is usually effected in quite different ways. In the UK the standard desliming method is the hydrocyclone. Hydrocyclones cutting at about 150µ offer a by-no-means perfect wash or perfect separation but do a reasonable job of both and also impart some small measure of scrubbing to the sand, which is useful when iron-rich clays loosely adhere to the grains. Hydrocyclones are cheap to install and can be mounted at great height in order to flume off sand into bottom draining bins or into conical naturally draining stockpiles. Their effective operation is governed almost entirely on a fixed mechanical condition, slurry density and, most importantly, the speed of the supplying slurry pump. In recent years a family of machines termed hindered-settling classifiers have become widely used in the UK silica industry. In this case a body of sand is teetered by a rising current of water and the coarser particles naturally report to the base of the unit. The density of the mass of teetered sand is continuously read by a differential pressure cell which pneumatically triggers a basal valve to open and close, thus releasing the coarser particles and maintaining a constant density in the machine, with therefore a constant grading of the desired product. This type of sand separation is most useful in making clean grading cuts or removing light or fine particles.

American practice is based largely on rake or screw classifiers, both machines pushing a gradually thickening sand pulp up an incline while the wash-water weirs over the back of the machine. Neither of these apparently cumbersome machines gives as good a wash as a hydrocyclone or a hindered-settling classifier and both are prone to losing sand with the wash-water. Another commonly seen American washing method is the elutriator, where a gently rising current of water is introduced into the base of a cone and excess wash-water weirs off the top, a technique mainly applicable to clay removal.

Removal of unwanted minerals

The extraordinary (and indeed most interesting) element of glass sand production is this aspect of its processing. Mineralogical purity is not normally specified for construction sands, though the presence of lignite, peat or shell are examples of impurities which can make a construction sand unacceptable. Foundry sand, while specifying a high (+95%) SiO₂ content, is classified by size range rather than chemical purity although alkali and acid demand may be specified for some moulding purposes. In glassmaking the



Froth flotation cells at the Byron operation of Martin Marietta

chemical purity of a silica sand is of paramount importance in determining the structural perfection and clarity or colour of the end-product. To understand the relevant processing techniques one must briefly note how iron-bearing minerals and various non-iron-bearing heavy minerals occur in sands, these modes of occurrence being:

- clays and agglomerates
- surface iron staining by minerals such as limonite, haematite, chamosite and siderite
- a mineral assemblage as above but held in cracks in the grain
- as discrete heavy minerals, both iron-bearing, eg ilmenite, magnetite, and non-iron-bearing, eg garnet, spinel, kyanite, chromite and tourmaline
- as mineral or stain included within the grain.

To cope with the removal of these groups of mavericks five families of treatment have grown up. They are listed below in order of increasing complexity and cost, along with notes on the type of contaminant which will be removed.

- 1 Washing - clays, some agglomerates, loose stain
- 2 Attrition scrubbing - agglomerates, surface staining
- 3 Froth flotation - heavy and iron-bearing minerals
- 4 Dilute acid leaching - strongly adhered surface staining
- 5 Hot acid leaching - effective removal of surface and sub-surface staining.

Dry or wet magnetic separation has been applied to removing magnetic minerals from glassmaking sands but as yet is most uncommon.

Washing processes

These are generally synonymous with silt removal and as such have been discussed. The washing process also serves to pulp the feed whereafter attrition, flotation and cold acid leaching are carried out on pulps of various densities.

Attrition scrubbing

This involves the high-speed agitation of a high-density (75-80% solids by weight) pulp to create conditions of maximum particle-to-particle contact in order to scrub off loose stain and break down clays and agglomerates. The process is enhanced if the pulp is made acid or alkali and several stages of attrition via intermediate washes may be required in a dirty feed. This practice is far more widespread in the USA where it is regarded as *de rigueur* in order to clean the sand prior to froth flotation or as a clay removal process prior to desliming. The variable cost, assuming a neutral scrub, is largely in the high power input required, normally about 3.75kW/tonne. Scrubbing is particularly applicable if a deposit is feldspathic; in this case the process not only ultimately lowers iron levels but also combats an over-high alumina content by breaking up and dispersing clays for

subsequent washing off. Most American plants have a sophisticated system of maintaining a high slurry density (without which the process is useless) by varying the make-up water input according to the amperage read on the first cell.

Froth flotation

Apart from glass sand, this almost ubiquitous process is applied to concentrating copper, zinc, phosphates, baryte and many other metallic and non-metallic minerals. Basically the process involves slurring the sand in an acid, alkali or neutral water-based pulp and then adding a 'collector', a hydrophilic (water repellent) reagent with a chemical affinity for iron. The conditioned pulp then passes into a flotation machine, a bank of linked 'cells' each agitated by a basal impeller. Compressed air is introduced below the impeller and a frothing agent added. Iron minerals coated with hydrophilic collector are buoyed up by rising air bubbles and report to the top of the cell where they are held in a stiff froth promoted by the frothing agent, usually some form of detergent. This iron and mineral rich froth is then mechanically scraped off to waste. Commonly used collectors are petroleum sulphonate (in an acid pulp), fatty acids and tall oils (in neutral or alkali floats). The chemistry of froth flotation and the many physical variables of the process are beyond the scope of this paper, although useful further reading is listed in references 3, 4 and 5.

All major producers of flint glass sand in the UK employ some degree of flotation. The commonly used float is Lower Greensand deposits and on the Millstone Grit in Staffordshire employs petroleum sulphonate collector in an acid (pH 3) environment. This type of float is also used at the Carolina Silica plant at Marston, North Carolina, in this case following two separate stages of attrition scrubbing. American flotation practice varies widely according to the level and type of contaminant in the feed and the particular product specification aimed at.

At PGS, Millville, New Jersey, an alkaline float has been found best for removing the troublesome refractory minerals kyanite and sillimanite. In California both Martin Marietta at Byron and Ottawa Silica at Oceanside use neutral floats. California State regulations governing water pollution are so stringent that acid flotation is practically precluded. A combination of tall oils, fatty acids and some petroleum sulphonate are used but the result is a less selective float. In this case achieving sufficient output to satisfy demand is currently over-riding the need to produce a product sand of good chemical purity. The nearest source of high-grade silica to California is 1,500 miles away in Missouri. In some cases this is shipped in and blended with local sands.

For the glass sand industry froth flotation is the universally used process for the removal of iron-bearing and heavy minerals. If the plant is of sufficient capacity and the cost of the necessary reagents can be stood, then up to 90% of discrete minerals can be removed. Alternatively, the process can be used to 'rough' the worst of the contaminants off to produce an acceptable end-product.

Dilute cold acid leaching

This process, applicable to the removal of stubborn surface iron staining, was pioneered by H. D. Segrove of British Industrial Sand Ltd³. It involves the slurring of the feed at high density in a turgid pulp made acid by sulphuric, or more effectively but expensively hydrofluoric, acid. To this is added solid sodium hydrosulphite and a leaching reaction is set up which partially dissolves iron from the surface of the grain. The Lower Greensand in England is treated in this way but the writer has never come across examples of its use outside the UK. American management with whom the process was discussed were horrified at the reagent costs involved.

Hot acid leaching

This process represents the, as yet, ultimate practical method

of reducing Fe_2O_3 levels present as staining or in cracks in the grain. The cost of the process is about double any combination of those previously discussed. The feed sand must first be dried before the addition of a specific quantity of sulphuric acid and a minimal moisture input to the hot dry sand. The whole mix is then slowly tumbled for 40–50 min in a refractory-lined drum before a thorough multi-stage final wash.

The plant involved was developed by Central Silica of Ohio, a small company who supply very local glass and ceramic markets. They lie intermediate between the Oriskany and St Peter sandstone major producers and can thus stand the high costs of the process because of lower freight charges. Hot acid leaching is employed in the UK to reduce Fe_2O_3 levels on heavily stained Millstone Grit. The inescapable high variable costs can be reduced slightly by using acid spent after another major industrial user's process.

General discussion of processing

The poorer quality the head material is, the more complicated the beneficiation plant must be. Various processes in sequence in four different plants are shown in the appendix. Number 1 shows what is simply a thorough washing plant, 2 adds multi-stage attrition scrubbing and flotation and 3, which has a cleaner feed than 2, employs a cold leach rather than an attrition stage. Number 4 illustrates to what length a producer will go to upgrade a material on the market's doorstep.

Dewatering

Glass sand being so fine, this is always an intractable problem. In Britain stockpiles or bottom-draining bins are normally used. In the US mechanical vacuum dewatering systems are often employed, either sucking moisture from below a moving conveyor or from beneath a rotating pad which is receiving and discharging sand at approximately 300° to each other.

Drying

A dichotomy exists in that all US glass sand is dried for sale, whereas almost all UK output is sold moist.

American companies almost always use fluid-bed dryers fired by natural gas or oil. Dust suppression is by wet arrestors or venturi scrubbers. An interesting exception is Martin Marietta's works at Wedron, Illinois, where sand dewatered in bunkers filled to capacity with a 25% solid slurry is grabbed and dropped above a nest of steam-filled tubes. As it dries the sand bridges over slats and eventually falls on to a conveyor belt. The steam is raised by coal-fired boilers.

STAFFING AND MANAGEMENT

Generally speaking American trade unions appear to have more influence on operating practice, though manning levels and demarcation are not obvious problems. Regional differences are marked. In New Jersey, for instance, there is no significant differential between operatives and fitters; in California, fitters earn more than half as much again. The practice of bidding is widespread, whereby the most senior man has an automatic right to any vacant job on the site.

Quarry and plant managers are very similar to their British counterparts, usually having progressed through the company for a number of years rather than having an academic background followed by a short period of intensive training. Safe working procedures and good housekeeping are, on the whole, given a slightly higher priority by US managers. Restoration and site after-use is a subject in its infancy in America.

ACKNOWLEDGEMENT

The writer expresses his thanks for all those, both in UK and the USA, who gave their assistance over the study tour on which this report is based.

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APPENDIX: Beneficiation processes at different plants shown in sequence

1 OTTAWA SILICA

Ottawa, Illinois

Monitoring

Scalping on quarry floor

Clay removal by elutriate

+500µ removal by two stage DSM sieve bends

Dewatering on moving belt vacuum filters

Drying for sale.

2 CAROLINA SILICA INC.

Marston, North Carolina

Dry and wet working

Scalping in trommel screens

+100µ slimes removal by hydrocyclones and screw classifiers

+500µ removal by screens and hindered-settling classifiers

Removal of iron coatings and adhered clays by two-stage attrition scrubbing in an alkaline pulp—intermediate hydrocyclone wash between scrubs

Heavy mineral removal by anionic flotation using petroleum sulphonate in an acid pulp

Hydrocyclone wash and dewatering on moving belt vacuum filter

Drying for sale.

3 BUCKLAND SAND & SILICA CO. LTD

Reigate, Surrey

Dry working

Scalping and removal of +2mm sand by screening

Removal of +500µ sand by hindered-settling classifier

Slimes removal by two-stage hydrocyclone wash

Removal of Fe-rich surface stain by cold acid leaching using HF and sodium hydrosulphite

Heavy mineral removal by anionic flotation using petroleum sulphonate and fatty acids in an acid pulp

Hydrocyclone wash to naturally draining stockpiles.

4 UG (SAND DEVELOPMENTS) LTD

Devilla Forest, Alloa

Drilling and blasting

Loading and hauling

Jaw crushing

Wet ball milling

+500µ removal by screening

Slimes removal by hydrocyclones

Removal of indurated Fe staining by hot acid leaching using sulphuric acid

Leachate removal by multi-stage hydrocyclone washing

Chromite removal by anionic froth flotation using petroleum sulphonate in an acid pulp

Hydrocyclone wash to naturally draining stockpiles.

Bench and pilot-plant beneficiation of calcium carbonate, sand and other industrial minerals

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ABSTRACT

This paper describes the background and markets for calcium carbonate and silica sand in Canada, as well as the results of recent test work carried out at the Ontario Research Foundation. Tests on sericite, tremolite, vermiculite, barite and graphite are also mentioned.

Introduction

The development and production of industrial minerals is frequently created through local industrial demands; for example, the development of kaolin as a filler in the paper industry and the use of calcium carbonate as a filler in plastics and as a paint pigment.

Canadian industry imports relatively large tonnages of certain industrial minerals, such as glass sand and calcium carbonate. In certain cases, the potential exists not only for these minerals to be produced in Canada to meet internal requirements, but also to open up export markets.

The purpose of this paper is to describe the research activities at ORF to assist Canadian companies to develop industrial mineral output.

Calcium Carbonate Background

Pure, white calcium carbonate is mined as marble in North America in such states as Georgia, Vermont, California, and Massachusetts. Marble deposits are known to exist in Ontario;

for example, in the Perth and Peterborough areas. The occurrence of chalk in North America is unknown. In Europe, however, chalk is used either by itself or mixed with ground marble.



P. D. R. Maltby

Peter Maltby graduated from the Royal School of Mines, London, in 1953. Since then, he has been employed in the Canadian mineral processing industry with such companies as Cominco Ltd., Denison Mines Limited and Falconbridge Nickel Mines Ltd. He has also spent

five years with the Mines Branch, Ottawa, and four years as manager of Ferroxx Iron Ltd., Prescott, Ontario. Since 1973, Mr. Maltby has been assistant director of metallurgy at the Ontario Research Foundation. He is a member of the CIM and IMM.

Keywords: Beneficiation, Industrial minerals, Calcium carbonate, Silica sand, Glass, Mineral processing.

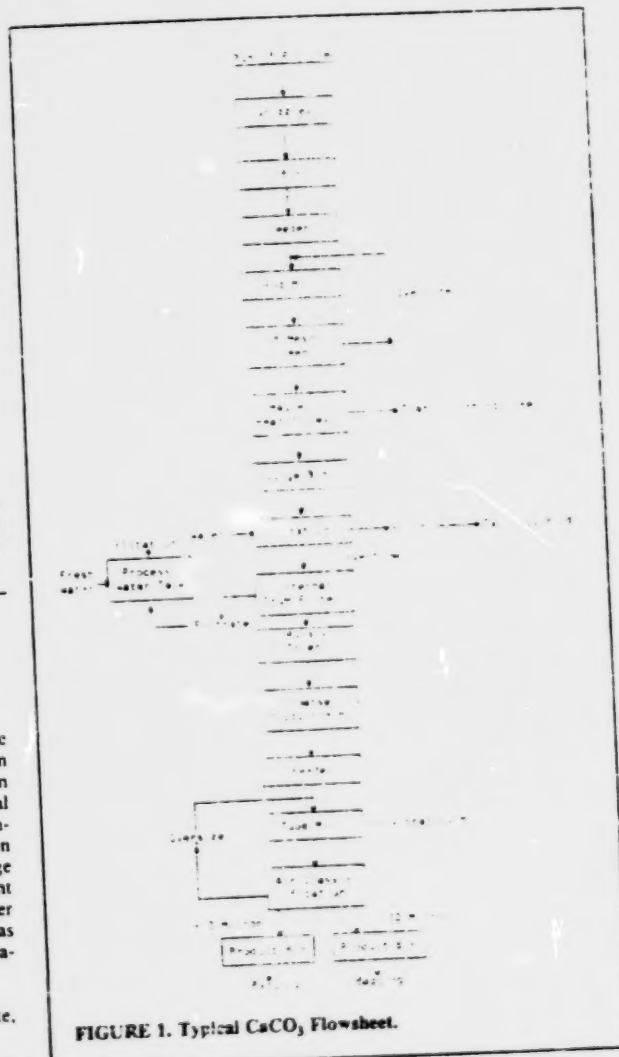


FIGURE 1. Typical CaCO_3 Flowsheet.

TABLE 1. Major uses for calcium carbonate (Canada)

Application	Approx. Annual Tonnage	Particle Size	Whiteness*	Price Range** (\$/short ton)
Carpets	30,000	90% -325 mesh	Not important	15 to 20
Tiles	60,000	35 to 200 mesh	not important	10 to 15
Joint Compound	40,000	80 to 100% -325 mesh	better than 85	15 to 25
Sealants, putty	30,000	100% -325 mesh	better than 85	20 to 70
Adhesives, plastics	+ 60,000	from -40 to 10 microns	95	50 to 100
Stucco, precast concrete	30,000	3/8 to 1/8 in.	not important	15 to 30
Garden stone	15,000	1-1/4 + 3/8 in.	not important	20 to 50
Paper	10,000	-10 microns	95	100 +
Feed and glass	100,000	-10 mesh	not important	10 to 20
Fertilizer	100,000	-4 mesh	not important	5 to 10
Scouring	20,000	-20 mesh	better than 85	30
Paint	20,000	10 microns	95	50 to 100

*green filter whiteness (MgO = 100%)

**excluding freight and bagging costs

Marble is mined usually by open pit, crushed, ground and beneficiated by conventional means. Purity is the optimum combination of whiteness, carbonate content, particle size and particle shape. Whiteness is a combination of purity and particle size. It increases as the surface area increases. In order to obtain maximum whiteness (96% with MgO = 100%), the Fe₂O₃ content must be below 0.10%. In the case of marble (sugar calcite), good crystallinity is of great importance in order to obtain maximum whiteness.

Precipitated calcium carbonate is produced by several chemical companies. It is more expensive than natural calcium carbonate. The main use for precipitated calcium carbonate is as a paper filler*.

Markets

A considerable market for various grades of calcium carbonate exists in Canada (mainly Ontario). The requirements of this market are shown in Table 1. The cheaper grades of calcium

carbonate, where whiteness is not too important and fineness is limited to a top size of 40 microns, are supplied by Canadian sources. The better grades for pigment and plastic use have, however, up to now, been supplied by imports amounting to several million dollars per year.

Calcium carbonate specifications vary widely for the same application due to individual company processes being slightly different. Many trade names are used, which further complicates any evaluation process. The properties that help to make calcium carbonate important as a pigment are whiteness, fine particle size (minus 10 microns), close particle size distribution, strong affinity for the binders used, good adhesion in highly loaded systems, and thus the ability to reduce shrinkage, and low cost in relation to the properties it contributes to the finished product.

Testing Results

Laboratory and pilot-scale tests have been done on representative samples of marble from Ontario to remove such impurities as chlorite and quartz. The flowsheet consisted of standard mineral processing equipment, as shown in Figure 1. The use of steel liners and balls in the grinding mills did not discolour the product, provided that any abraded iron was removed by low-intensity wet magnetic separation. Grinding may be done wet or dry; the choice is one of economics. With dry grinding, the feed must be dried. However, it does allow for the removal and sale of fines collected by air classification. Typical grinding power requirements were 8 kwh per short ton of flotation feed.

Impurities are removed after grinding to liberation, either by (1) a fatty acid calcium carbonate float or (2) an amine float of the siliceous gangue minerals. The choice is dependent on the metallurgical efficiency and on economics.

*Ref: *Industrial Minerals*, p. 37, December 1977.

TABLE 2. Typical chemical analysis of calcium carbonate flotation concentrate

Constituent	%
CaCO ₃	97
MgCO ₃	2.7
SiO ₂	0.15
Fe ₂ O ₃	0.10
Al ₂ O ₃	0.05
LOI	44
Green filter whiteness	95 or higher
Other metals	trace

TABLE 3. Typical compositions of some glass-making raw materials

	Oxide Composition, %									% Glass Made	% Fusion Loss	Sub Density (m/cu ft)
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Cr ₂ O ₃	TiO ₂	CaO	MgO	Na ₂ O	K ₂ O			
White sand	99.7	0.08	0.025	0.0002	0.02	0.01	0.01	0.004	0.005	99.9	0.1	95
Yellow sand	99.1	0.25	0.150	0.0020	0.05	0.01	0.01	0.015	0.050	99.6	0.4	87
Soda ash	—	—	0.002	—	—	—	—	58.0	—	58.0	42.0	63
Calcite limestone	0.7	0.1	0.075	0.0010	—	54.7	0.60	—	—	56.2	43.8	91
Dolomite limestone	0.5	0.3	0.075	0.0005	—	31.0	21.0	—	—	52.9	47.1	90
Feldspar	68.0	18.4	0.075	0.0003	0.01	1.4	0.02	6.9	4.0	96.8	0.2	80
Apilite	60.5	23.0	0.410	0.0003	0.20	5.6	0.05	6.1	2.9	96.8	1.2	90
Nepheline syenite	59.5	23.9	0.085	0.0003	—	0.2	—	10.5	5.0	96.2	0.8	95
Self cake	—	—	0.003	—	—	—	—	43.5	(SO ₃)/56.2	43.5	56.5	85
Fluorspar	2.5	—	0.19	—	—	85.8	(F ₂)/143.5	—	—	68.5	31.5	91
Borax (anhydrite)	(B ₂ O ₃)/(69.2)	—	—	—	—	—	—	30.8	—	100.0	—	82
Sodium nitrate	—	—	—	—	—	—	—	36.5	—	36.5	63.5	—
Arsenic	(As ₂ O ₃)/(100.0)	—	—	—	—	—	—	—	—	—	—	—
Selenium	(Se)/(100.0)	—	—	—	—	—	—	—	—	—	—	—
Iron pyrite	3.1	—	63.2	0.005	—	—	—	—	(S)/(50.3)	66.3	33.7	125
Iron chromite	1.4	15.0	28.0	45.0	—	—	10.4	—	—	99.8	0.2	88
Gypsum	3.5	0.9	0.33	—	—	30.9	1.3	—	(SO ₃)/(42.7)	38.9	61.1	75
Barite	—	—	—	—	—	(BaO)/(137.3)	—	—	(SO ₃)/(34.3)	65.7	34.3	120

TABLE 4. Typical chemical and physical working specifications on glass raw materials

Material	(A)	(B)
	Chemical Spec.	Physical Spec.*
White Sand	SiO ₂ over 99%	+ 20 mesh - 0
	Fe ₂ O ₃ - 0.030% max.	+ 30 mesh - 1% max.
	Cr ₂ O ₃ - 0.0003% max.	-100 mesh - 15% max.
Yellow Sand	SiO ₂ over 98.5%	+ 20 mesh - 0
	Fe ₂ O ₃ - 0.20% max.	+ 30 mesh - 1% max.
	Cr ₂ O ₃ - 0.005% max.	-100 mesh - 15% max.
Soda Ash	Na ₂ CO ₃ over 99%	+ 16 mesh - 0
	NaCl - 0.5% max.	+ 30 mesh - 3% max.
	Fe ₂ O ₃ - 0.001% max.	-200 mesh - 3% max.
Limestone	CaO + MgO over 54%	+ 16 mesh - 1% max.
	Fe ₂ O ₃ - 0.10% max.	+ 20 mesh - 15% max.
		-100 mesh - 20% max.
Feldspar	Al ₂ O ₃ over 19%	+ 16 mesh - 0
	Alkali - over 11%	+ 20 mesh - 1% max.
	Fe ₂ O ₃ - 0.10% max.	-100 mesh - 25% max.
Nepheline Syenite	Al ₂ O ₃ over 22%	+ 30 mesh - 0
	Alkali - over 13%	+ 40 mesh - 3.5% max.
	SiO ₂ - 62% max.	-100 mesh - 25% max.
Aplite	Fe ₂ O ₃ - 0.10% max.	
	Al ₂ O ₃ over 22%	+ 16 mesh - 0
	Fe ₂ C ₃ (low iron) - 0.10% max.	+ 20 mesh - 2.5% max.
Salt Cake	Fe ₂ O ₃ (high iron) - 0.45% max.	+ 30 mesh - 25% max.
		-100 mesh - 25% max.
	Na ₂ SO ₄ over 99%	+ 16 mesh - 0
Gypsum	NaCl - 0.002% max.	+ 20 mesh - 1% max.
	Fe ₂ O ₃ - 0.20% max.	+ 30 mesh - 2% max.
		-100 mesh - 54% max.
		+ 16 mesh - 0
		+ 20 mesh - 0.5% max.
		+ 30 mesh - 5% max.
		-100 mesh - 25% max.

*Note: Physical specification on grain size distribution based on % retained on U.S. Series screens.

For high-purity, high-whiteness calcium carbonate, a final product of the composition shown in Table 2 is required. Because the flotation concentrate was about 100 mesh, it must be dewatered and ground finer either by wet or dry means.

In general, calcium carbonate pigments are dry ground with air classification, which is more precise than wet classification. The dry grinding mills used include roller, tube and vibration mills. For some applications, such as paper coatings where a particle size below 2 microns is required, wet sand mills are used. In this case, the fine product is filtered and sold directly to the end user as a wet filter cake.

In physical tests, to determine the suitability of the final product, the Ca:Mg does not appear to be significant provided the contaminants are low and the whiteness is acceptable.

Silica Sand

Background

The glass industry is a major user of many industrial minerals,

TABLE 5. Bench-scale results of treating sand

Product	Weight Analysis, %		
	%	Fe ₂ O ₃	Al ₂ O ₃
-30 + 150 mesh screen fraction of raw feed still containing some -150 mesh material	100.0	0.051	0.45
-30 + 150 mesh product after wet washing on 150 mesh screen	96.4	0.036	0.45
Exolon H L dry magnetic separator Non-magnetic product			
— after 1 pass	95.7	0.038	0.45
— after 2 passes	93.1	0.021	0.43
— after 3 passes	90.9	0.029	0.41
— after 4 passes	89.2	0.029	0.42

among which silica sand ranks high, in the manufacture of its products. Tables 3 to 9 show typical chemical and physical specifications of some glass-making raw materials. As can be seen, sand suitable for glass manufacture must meet stringent

TABLE 6. Materials balance — wet grinding and classification — silica sand pilot-plant results

	Weight		% Fe ₂ O ₃	% Al ₂ O ₃	ppm Cr ₂ O ₃
	lb/hr	%			
Rapifine DSM Screen Product (-20 + 150 mesh).....	1860	81.6	0.059	1.25	<5
Rejects:					
Rapifine DSM Screen Undersize (150 mesh)....	112	4.9			
Hydroseparator Overflow Fines.....	308	13.5		13.2	
New Feed.....	2280	100.0	0.12	2.29	<5
Intermediate Products:					
20 Mesh Screen Oversize (rod mill circulating load).....	680	29.8			
Grinding Steel Wear.....	10	0.4			
Rod Mill Discharge.....	2970	130.2			
20 Mesh Screen Oversize (circ. load).....	680	29.8			
20 Mesh Screen Undersize.....	2290	100.4			
Magnetic Separator Magnetics.....	10	0.4			
Magnetic Separator Non-Magnetics.....	2280	100.0			
Hydroseparator Underflow.....	1972	86.5			

chemical and physical requirements.

To generalize, a natural light-coloured quartzite, sandstone or quartz, which readily breaks down, washes to a light colour with at least 95% of its grains between 20 and 150 mesh with a fairly uniform size frequency distribution, is a potential multi-purpose industrial silica raw material. If further inspection reveals that the individual quartz grains are free of identifiable

blemishes, e.g., black iron-bearing inclusions or a notable percentage of deeply coloured grains, the chances are that, with specialized preparation, the sand might qualify for higher-grade use.

Defects that plague most silica source materials, particularly where the glass industry is concerned, include small amounts of nickel, chromium, copper and cobalt. Even trace amounts of these metals are deleterious because of their high colourant or defect-producing properties when dissolved in molten glass.

Silica Sand Testing at ORF

Bench Testing

Beneficiation tests have been done at ORF on samples of (a) a silica sand deposit in Quebec and (b) a silica-kaolin deposit in Ontario*.

Bench-scale tests were done on both samples to investigate the means to remove clay minerals by wet scrubbing and the removal of iron contamination by dry or wet high-intensity magnetic separation. The feed samples were first sized between 30 and 150 mesh. In the case of the sample from the Quebec deposit, flotation tests were run to try to float impurities. These tests resulted in a reduction in the alumina content of the sand, but not the iron. The results obtained with dry high-intensity magnetic separation were better in terms of both Fe and Al removal; they are summarized in Table 5.

*Described in detail in *CIM Bulletin*, July, 1970; D. E. Smith and M. K. Murthy; Silica-Kaolin Deposits of Algonquin Mines Limited.

TABLE 7. Materials balance — high-intensity dry magnetic separation and dry screening — silica sand pilot-plant results

	Weight %	% Fe ₂ O ₃	% Al ₂ O ₃
Rapifine Screen Product (dried).....	81.6		
Sweco 150 Mesh Screen (single pass):			
Undersize Rejects.....	4.4		
Oversize Product.....	77.2	0.051	0.45
Exolon High-Intensity Dry Magnetic Separator (single pass):			
Magnetic Fraction.....	3.2		
Magnetic Middling Fraction.....	1.3		
Total Rejects.....	4.5		
Product (-20 + 150 mesh).....	72.7		
Sweco 30 Mesh Screen (single pass):			
Undersize Rejects.....	2.1		
Product -30 + 150 Mesh.....	70.6		

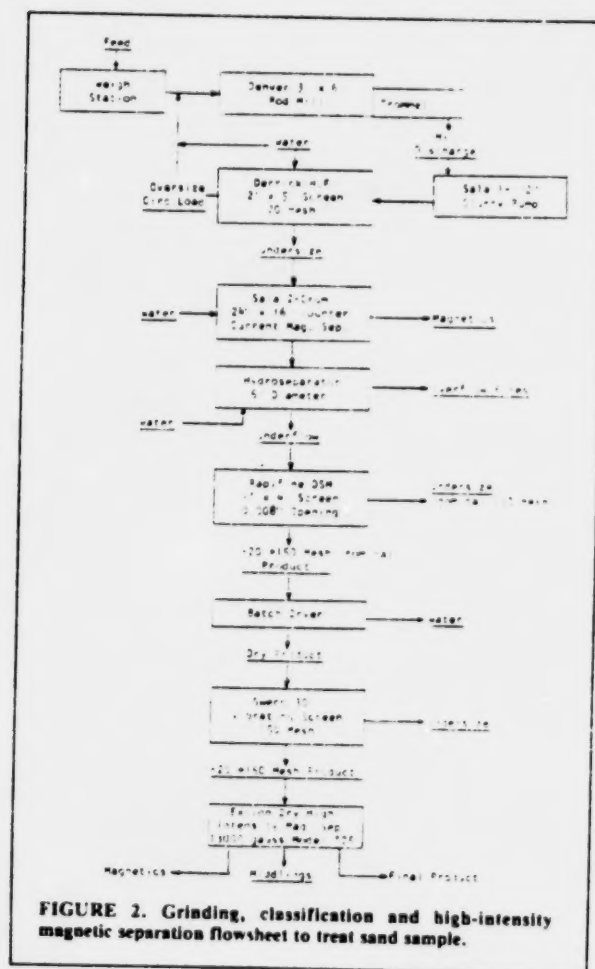


FIGURE 2. Grinding, classification and high-intensity magnetic separation flowsheet to treat sand sample.

TABLE 8. Water balance — wet grinding and classification — silica sand pilot-plant results

	Dry Solids (lb/hr)	Pulp Density (% Solids)	Water — lb/hr	
			Content	Addition
Rod Mill:				
New Feed.....	2280	98.0	46	
Circulating Load (+ 20 mesh).....	680	50.2	675	
Steel Wear.....	10			1178
Discharge.....	2970	61.0	1899	
20 Mesh Screen:				
Oversize (circ. load).....	680	50.2	675	
Undersize Product.....	2290	18.7	9956	8732
Magnetic Separator:				
Magnetics.....	10	16.7	50	
Non-Magnetic Product.....	2280	11.3	17897	7991
Hydroseparator:				
Bottom Water.....	—	—		5344
Overflow.....	308	1.4	21692	
Underflow.....	1972	59.4	1549	
Rapifine DSM Screen:				
Undersize.....	112	12.4	789	
Oversize Product.....	1860	71.0	760	

TABLE 9. Feed and product structures — silica sand pilot-plant results

Head Sample			Product*		
Size	Weight %		Mesh	Weight %	
	ON	Passing		ON	Passing
+ 2 in.	1.9	98.1	20		100.0
1 in.	5.8	92.3	28	2.9	97.1
1-1/2 in.	10.3	82.0	35	16.6	80.5
3 mesh	9.6	72.4	48	26.1	54.4
4 mesh	4.1	68.3	65	22.3	32.1
6 mesh	6.9	61.4	100	19.1	13.0
8 mesh	8.3	53.1	150	8.1	4.9
10 mesh	9.6	43.5	-150	4.9	
14 mesh	8.7	34.8	Total	100.0	
20 mesh	8.0	26.8			
28 mesh	6.1	20.7			
35 mesh	5.2	15.5			
48 mesh	4.4	11.1			
55 mesh	3.4	7.7			
100 mesh	2.5	5.2			
150 mesh	1.3	3.9			
-150 mesh	3.9				
	100.0				

*After dry screening on the Sweco 30-in. unit at 150 mesh.

**Pilot-Plant RapiLine DSM Screen
Oversize Product (before dry screening)**

Mesh Size	Weight %
-20 +150	91.2
-150	8.8
Total	100.0

Pilot-Plant Tests

Pilot-plant tests were done on a 20-ton sample of sand using the flowsheet shown in Figure 2. Rod mill feed was fed at the rate of 1860 lb/hr. The mill discharge was pumped over a 20-mesh screen, with the screen oversize returning to the mill feed. After low-intensity magnetic separation, the non-magnetics were deslimed and the deslimed sand screened to produce a nominal minus 20 plus 150 mesh product for drying, further screening and final dry high-intensity magnetic separation. The results of material balances, water balance, and feed and product size structures are shown in Tables 6 to 9.

From the pilot-plant test, several tons of sand were produced for subsequent evaluation, with the analysis indicated in Table 10.

TABLE 10. Evaluation of pilot-plant silica product

Chemical Properties		Size Grading	
		Mesh	Wt. %
SiO ₂	99.25 %	+ 30	nil
Fe ₂ O ₃	0.030 %	-30 +100	13
Al ₂ O ₃	0.42 %	-100 +200	87
TiO ₂	0.04 %	-200	nil
LOI	0.10 %		
Cr ₂ O ₃	4 ppm		

Test Work on Sericite, Tremolite and Vermiculite

Dry Screening and Air Tabling Tests

Sericite, tremolite and expanded vermiculite samples have been treated separately by dry screening and air tabling to remove quartz and silicate impurities. Where required, dry high-intensity magnetic separation has been used to eliminate residual iron-bearing silicates.

Test Work on Barite

Experience at ORF on testing barite drill core samples has shown that sink-float tests, using heavy liquids up to 3.3 s.g., indicate their suitability in oil well drilling applications to control the specific gravity of water and oil-base sands.

Such specifications call for a barite concentrate with a minimum specific gravity of 4.2, a maximum 3% + 20 mesh and a maximum 5% + 325 mesh. Fine impurities of silica and silicates are often sufficient to make it impossible to meet these specifications. In order to obtain a specific gravity of 4.2, a barite containing at least 92% BaSO₄ is required.

Test Work on Graphite

Several graphite samples from various areas in Canada have been tested at ORF. Preparation of the crude ore is important in the beneficiation of graphite in order to minimize the breakdown of flake graphite, which commands the highest price. Pebble milling to replace rod or ball milling can be effective in increasing the yield of flake graphite (+ 48 mesh).

In general, graphite concentrates containing more than 90% carbon are required for marketing. Fine graphite has been beneficiated successfully at ORF using a frother and a gangue depressant such as sodium silicate.

"Sympromines"—1st World Symposium on Mining Industry Public Relations

Executives, operating managers and public relations experts of the world mining industry will meet in Brussels, Belgium, at the time of its millenium, on September 13, 14 and 15, 1979, to attend the first World Symposium dealing with the public relations problems of the industry.

Organized under the triple sponsorship of the European Federation of Public Relations (CERP), two internationally specialized magazines, *World Mining* and *World Coal* (U.S.A.), and Union Minière (Belgium), the meeting will take place at

the Brussels Hilton. It will deal with important current questions of concern not only to the specialists, but also to the public, such as: environmental protection; pollution and ecologists' movements; safety in mines; expropriations; nationalizations; raw material supplies; strategic stockpiles; international relations; north-south exchange; transfer of technology; exploitation of the ocean mineral resources; financing mining; competition; profitability; employment; training; education; mining industry of the future, etc.

The relations of the mining industry with the mass media—press, radio, TV, cinema—will be also discussed through cases studies.

Further information about this Symposium can be obtained from "Sympromines"—c/o Public Relations Service, Union Minière, Rue de la Chancellerie, 1-B-1000 Brussels, Belgium; Phone 513.14.63; Telex 21.551.

In the U.S.A.: "Sympromines"—c/o World Mining—World Coal, 500 Howard Street, San Francisco, CA 94105; Phone 415-397-1881; Telex 278273.

27

Pilot Plant Evaluation of an Anionic Detergent-Type Reagent for Beneficiation of a Glass Sand

by Robert M. Lewis

Silica sand deposits are usually contaminated with various heavy minerals which must be removed to make the silica useful for flat-glass production. Research was undertaken to develop a better procedure for producing flat-glass-grade silica. Batch tests revealed that anionic detergent-type reagents had considerable promise. Pilot plant tests were run to compare the effectiveness of anionic detergent-type reagents with petroleum sulfonate in the removal of heavy minerals from a potential glass sand. Another slightly modified commercial procedure also was evaluated for comparison. In the pilot plant trials, utilization of the anionic detergent flotation reagents did not produce quite as good results as petroleum sulfonate. It is likely that flat-glass-grade sand could be produced with the anionic detergent reagents if more extensive pilot plant tests were conducted.

Considerable interest has been shown by several companies in establishing mining operations in North Carolina and neighboring states for the production of silica for use in making glass. This interest has been intensified by the construction of several plants for production of glass products, including one of the world's largest flat-glass plants—the Libbey-Owens-Ford Company (L-O-F) plant at Lauffenburg, N.C.

In the past, several companies solicited the services of the Minerals Research Laboratory (MRL), North Carolina State University, for batch testing of sand samples using established procedures or experimental procedures of their choosing. Pilot-plant operations were performed on ores from different parts of North Carolina and neighboring states. Some procedures were successful; others produced satisfactory glass-grade silica but had excessively complicated flow-sheets.

State-supported research was undertaken to develop other flotation procedures for the efficient and economical removal of heavy-minerals contaminants from silica ores. The ultimate objective of this research was the production of glass-grade silica from sites near existing glass plants.

An efficient and economical flotation procedure using an anionic detergent-type reagent was developed and found to be effective in batch tests. This reagent is of particular interest because it is rapidly biodegradable. A pilot plant was constructed to test the procedure in a continuous operation. Process variables were standardized in a series of preliminary runs so that direct comparisons could be made of the effects of various types and combinations of reagents. It was realized that this would not permit optimum adjustment or product grade for each test. Ten pilot-plant tests were carried out comparing the new procedure with a commercial procedure and a slightly modified commercial procedure. Six tests, including the new procedure, produced products containing from 0.041 to 0.527 g of +70 mesh refractory heavy minerals per 100 lb of sand. More than 98.6% of the heavy minerals contaminants were removed in these tests.

Procedure

Ore—Approximately 10 tons of ore from the Sand Hills area in the vicinity of Cognac, N.C., were shipped by truck to MRL for pilot plant processing. A representative sample of the ore contained 0.51% heavy minerals in the deslimed +140 mesh

fraction as determined by heavy-liquid (sp gr 2.96) techniques. The average for the deslimed +140-mesh feed to flotation for the ten pilot plant tests was 0.49% heavy minerals. The average chemical analysis of the deslimed flotation feed for 10 tests was: 0.17% Fe_2O_3 , 0.39% Al_2O_3 , 0.019% Na_2O , 0.032% K_2O , and 0.13% loss on ignition (LOI).

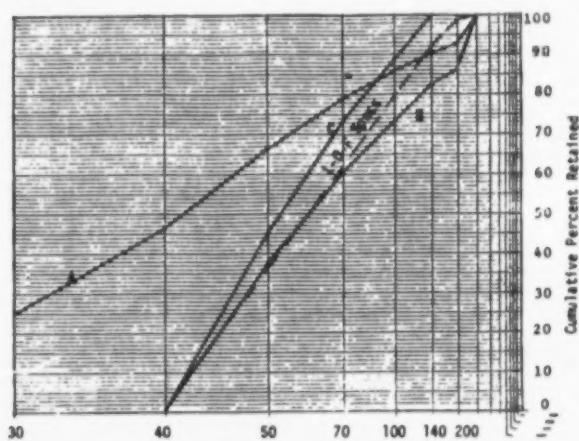
Specifications—The L-O-F glass sand specifications used in this research were: 0.080% Fe_2O_3 content with an acceptable variance of 0.040% maximum and refractory heavy minerals, such as zircon, kyanite, sillimanite, chromite, corundum, and andalusite, are limited to 0.200 g of +70 mesh refractory minerals in 100 lb of sand. The latter is equivalent to 0.00044% by weight, 4.4 ppm, or 1.0 lb in 138 tons. In addition, size specifications are included as discussed below. L-O-F glass sand specifications were used for two reasons. First, these specifications are typical of those in the flat-glass industry, and they are considerably more stringent than those of the glass container industry. Secondly, if glass sand is produced in North Carolina, L-O-F would be the largest potential customer.

Sizing—Screen analyses of head feed ore, ore with +40 mesh fraction removed, and ore with +40 and -140 mesh fractions removed were compared with L-O-F size distribution specifications, Fig. 1. Approximately 47.0% of the ore was coarser than 40 mesh, and 9% was finer than 140 mesh. The remaining 44% was of intermediate size. Removing the +40 mesh fraction produces a product containing an excess of -140-mesh material. The -140-mesh material could be removed in the desliming stage; however, this would leave a product coarser than that described in L-O-F specifications. A pilot-plant rod-milling test was undertaken to adjust the grind so that deslimed ore could be milled to produce a product approximating the required size specifications, Fig. 2. The charge consisted of eleven 1½ in × 32 in rods and three 1 in × 32 in rods with a total weight of 190 lb. Screen analyses of products from six pilot-plant tests are shown in the figures in Appendix A.

Pilot Plant Operation—The flowsheet for the pilot plant is shown in Fig. 3, and the details of the individual runs are given in the appendixes. Approximately 300 lb of ore per hr were transported by a belt conveyor from a hopper to a pulper. Here water was added and the pulp was agitated for 5 min. The material was pumped to a cyclone. The cyclone overflow slimes discharged to waste, and the underflow discharged to a rod mill. The ore was ground at 24% solids for a retention time of approximately 5 min. Rod mill discharge was passed over an integral trommel screen for removal of +30-mesh oversize material which was discarded as waste. The screen-undersize material was pumped to a cyclone for desliming. The cyclone overflow slimes discharged to waste, and the underflow discharged to a spiral classifier for

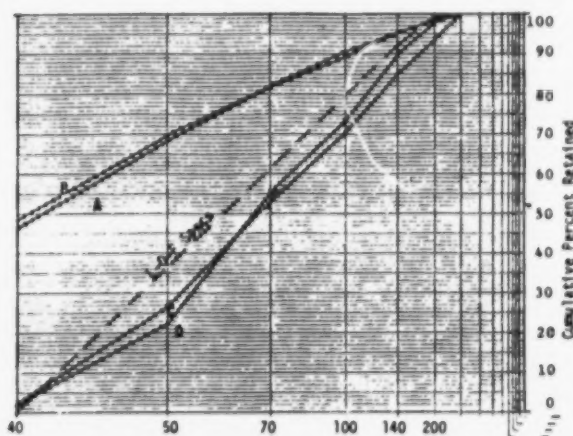
R. M. LEWIS, Member SME, is Senior Mineral Engineer, Minerals Research Laboratory, North Carolina State University, Asheville, N.C. TP 74H217. Manuscript, July 15, 1974. Discussion of this paper submitted in duplicate prior to Sep. 15, 1976, will appear in SME Transactions, December 1976 and AIME Transactions, 1976, Vol. 260.

additional slime removal. In the tests where a scrubber was used (Tests 8, 9, and 10), the cyclone underflow was dewatered preparatory to attrition scrubbing. In these tests, the



A		B		C		D	
Head Feed		+40 M. Remove		+40 & -140 M. Removed		L-O-F Specs	
Mesh U.S.	Per Cent	Per Cent Cumulative Weights	Per Cent	Per Cent Cumulative Weights	Per Cent	Per Cent Cumulative Weights	Per Cent
30	25.0	25.0	0.0	0.0	0.0	0.0	0.0
40	21.7	46.7	0.0	0.0	0.0	0.0	0.0
50	19.3	66.0	0.0	0.0	0.0	0.0	0.0
70	12.5	78.5	0.0	0.0	0.0	0.0	0.0
100	6.3	84.8	12.5	79.3	15.0	89.0	0.0
140	3.2	88.0	15.0	94.3	17.0	100.0	97.0
200	2.3	90.3	15.0	100.0	17.0	100.0	99.5
250	2.2	92.5	15.0	100.0	17.0	100.0	100.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	

Fig. 1—Screen analysis of head feed, head feed with oversize removed, head feed with oversize and undersize removed, and L-O-F product specifications.



A		B		C		D	
Pulper Disch.		Rod Mill Feed		Rod Mill Disch.		Silica Prod.	
Mesh U.S.	Per Cent	Per Cent Cumulative Weights	Per Cent	Per Cent Cumulative Weights	Per Cent	Per Cent Cumulative Weights	Per Cent
30	45.0	45.0	45.0	45.0	2.0	2.0	2.0
40	21.7	66.7	45.0	90.0	25.0	27.0	27.0
50	12.5	79.2	45.0	95.0	25.0	52.0	52.0
70	7.7	86.9	45.0	97.0	25.0	77.0	77.0
100	5.3	92.2	45.0	99.0	25.0	89.0	89.0
140	1.8	94.0	45.0	100.0	25.0	97.0	97.0
200	1.8	95.8	45.0	100.0	25.0	100.0	100.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	

Fig. 2—Screen analysis of products from various stages of pilot plant processing.

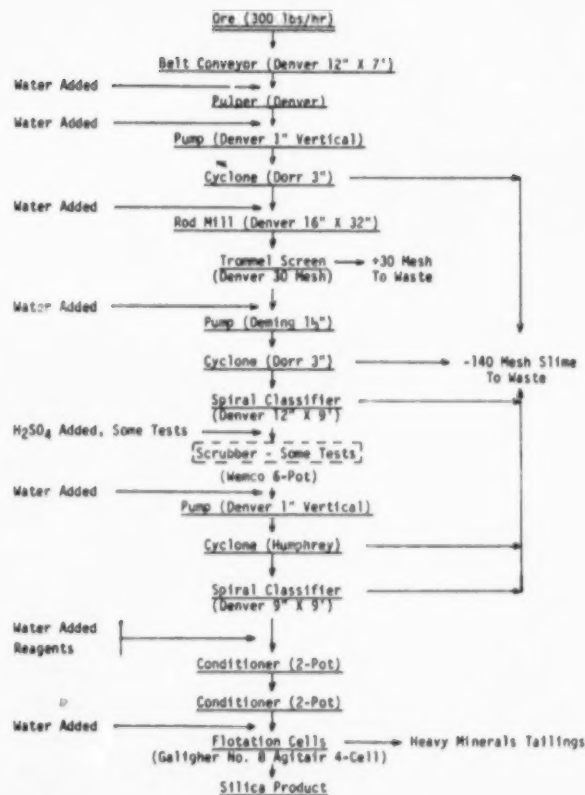


Fig. 3—Pilot plant flowsheet.

high-density material from the classifier was attrition-scrubbed at 70% to 75% solids for 20 to 25 min in a pulp containing 2.0 lb of 66° Baume H₂SO₄ per ton of ore (added as a 5% acid solution).

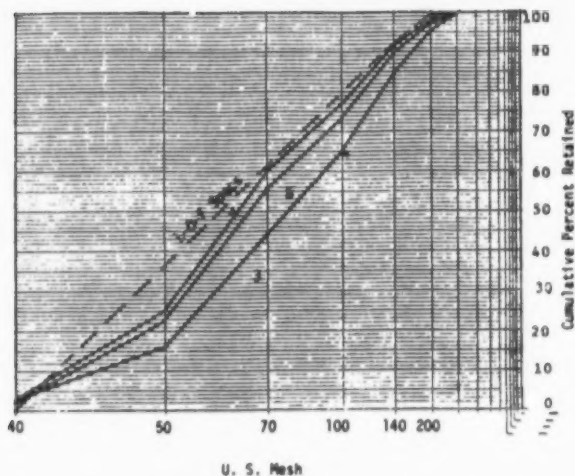
Depending on which pilot plant test was being conducted, the scrubber discharge material or the unscrubbed sand product from the first spiral classifier was pumped to a cyclone for desliming. The cyclone-overflow slimes discharged to waste, and the underflow material discharged to a spiral classifier for additional slime removal and dewatering preparatory to conditioning.

The sand product from the classifier was conditioned for approximately 5 min at 60% to 65% solids in a pulp containing the reagents being investigated. The material flowed to a second set of conditioners for an additional conditioning time of 6 min at 60% to 65% solids to insure sufficient coating of mineral particles. The conditioned material flowed to the flotation cells where the contaminant minerals were removed as a froth product, and the silica product was recovered in the machine-underflow discharge.

Process Control and Analyses

Timed samples of ore feed, flotation feed, slimes, tailings, oversize, and silica product were taken during the testing to determine material balances. Chemical analyses were obtained on the feed to flotation, tailings, and silica product. Heavy liquid separation of 100-g samples was used to determine heavy mineral content of feed to flotation and tailings. One hundred-gram samples of the silica product was screened on 70 mesh and both fractions were subjected to heavy liquid separation to determine heavy mineral content of sized fractions and total silica product. Each sample contained approximately 50 g.

It was felt that the amount of heavy minerals obtained from heavy liquid separation of 50 g of silica product would be so small being in the range of 0.0002 g that a weighing error might incur. Therefore, in Tests 3, 4, 5, 6, 8, and 9, in addition



	L-O-F Specs	Test 3		Test 4		Test 5	
Mesh	Per Cent	Per Cent Cumulative Weights	Per Cent	Per Cent Cumulative Weights	Per Cent	Per Cent Cumulative Weights	Per Cent
40		0.1	2.5	2.5	2.5	2.5	2.4
50			13.7	16.2	22.7	25.2	27.7
70			28.2	48.4	48.9	60.1	55.5
100			20.8	65.2	17.0	77.1	73.5
140		92.0	19.6	84.8	4.8	91.9	86.6
200		99.5	10.6	95.4	5.2	96.5	97.1
250		100.0	5.5	100.0	1.1	100.0	97.7
Total			100.0		100.0		100.0

Fig. 4—Screen analysis of pilot plant products.

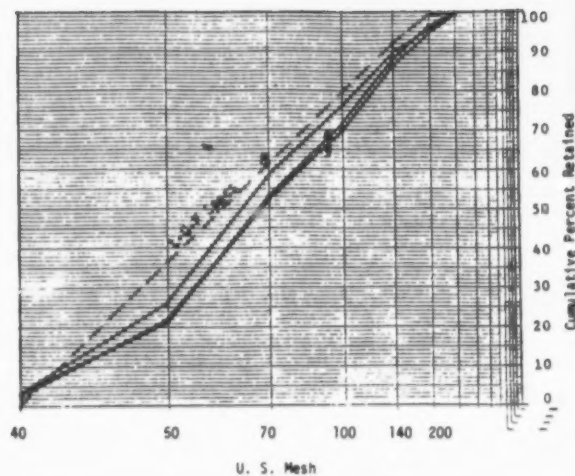
to the above determinations, 2500-g samples of the bulk silica products were screened on 70 mesh, and the plus and minus fractions were separated in heavy liquid. The heavy-minerals content was determined for both screen fractions and the total product. The heavy minerals were leached for 4 to 5 min in a boiling 1:1 solution of HCl and water. Water was added to dilute the HCl, which was then removed by decantation. The heavy minerals were leached with concentrated HNO₃ for 3 min, mainly to remove any pyrite which might be present. The refractory heavy minerals were determined by separating the leached heavy minerals with a Frantz isodynamic magnetic separator. The refractory minerals reported to the nonmagnetic product along with some nonrefractory minerals. Grain counts were made of the +70 mesh and -70 mesh fractions to determine the exact amount of refractory minerals present in the product, and these are the results presented in the tables in the appendices.*

Size distributions of silica products were obtained by screening on a rotap. Water distribution to equipment was monitored with flowrators, and water consumption was determined with a totalizing meter.

Comparison of L-O-F and MRL Analyses—Fifty-pound samples of products from Tests 3, 4, 5, 6, 8, and 9 were sent to the L-O-F laboratory in Toledo, Ohio, for evaluation. A comparison of L-O-F data with MRL data is shown in Appendix C and explained in the discussion section.

New Flotation Process—Four of the ten pilot-plant runs used the new heavy-mineral flotation process. The primary feature of this procedure is the use of detergent-type reagents, such as an equal mixture of sodium alcohol ether sulfate (Tex-Wet 1158) and a dodecylbenzene sulfonic acid (Tex-Wet 1197), as heavy minerals collectors in an acid circuit for froth flotation. These reagents referred to in the results as Tex-Wet reagent were obtained from Intex Products, Inc., Greenville, S.C.; however, other brands of similar chemicals were satisfactory in batch tests. The reagent adheres to the contaminant minerals, which are removed in the froth prod-

*Grain counts and minerals identification were performed by Carl Mersch, geologist with the Division of Resource Planning and Evaluation.



	L-O-F Specs	Test 6		Test 8		Test 9	
Mesh	Per Cent	Per Cent Cumulative Weights	Per Cent	Per Cent Cumulative Weights	Per Cent	Per Cent Cumulative Weights	Per Cent
40		0.1	3.0	3.0	3.2	2.9	2.9
50			18.3	21.3	23.2	25.4	26.0
70			31.8	51.2	37.4	58.8	56.3
100			16.2	71.4	19.5	76.1	77.5
140		92.0	16.6	88.0	19.5	89.6	88.2
200		99.5	8.6	96.6	8.1	95.8	95.0
250		100.0	1.4	100.0	1.1	100.0	5.0
Total			100.0		100.0		100.0

Fig. 5—Screen analysis of pilot plant products.

uct. Silica is not affected by the collector and is suppressed by the acid media at low pH; hence it is removed at the bottom of the chamber.

Other Flotation Processes—For comparison purposes, a pilot-plant test was performed on the commercial process in which petroleum sulfonate was the heavy-mineral collector. A second, modified commercial process, in which a fatty acid was used as the collector, was also included for comparison purposes. In addition, combinations of these reagents with the experimental detergent-type reagent were evaluated. Pilot plant Tests 1 through 7 were run without scrubbing, and Test 8, 9, and 10 were run with scrubbing.

Results

The pilot plant tests are described and the results obtained from selected pilot plant tests are given in Appendix A. The first two pilot-plant runs involved equipment adjustment and pilot-plant tune-up. Tex-Wet detergent-type reagent was used in both tests, with the lower amount of reagent giving the better grade product; however, the silica products from the first two tests were out of range of the specifications concerning +70-mesh refractory heavy minerals; therefore, the test data are not included in the appendix.

The silica produced in Test 3, Table 1, using fatty acid with the Tex-Wet reagent, contained 0.260 g of +70-mesh refractory heavy minerals per 100 lb of sand; and the silica yield was 84.3%. The total content of refractory heavy minerals in the silica product was 0.891 g per 100 lb of sand.

Petroleum sulfonate was used as the collector in Test 4, Table 2. This reagent is used commercially for sand beneficiation, and this run was included as a control. In previous research at the MRL, the use of petroleum sulfonate as a heavy-minerals collector in sand beneficiation produced the best results. The silica produced in Test 4 contained 0.082 g of +70-mesh refractory heavy minerals per 100 lb of sand, and the silica yield was 74.8%. The total content of refractory-heavy-minerals in the silica product was 1.178 g per 100 lb of sand.

Table 1. Pilot Plant Test No. 3

Sample	Physical Data				Chemical Analysis, %				
	Wt %	% HM	g per 100 lb sand		Fe ₂ O ₃	Al ₂ O ₃	Na ₂ O	K ₂ O	LOI
+30 Mesh	0.2								
H.M. Float	2.3	23.5							
-140 Slime	13.2				4.30	1.40	—	—	—
+70 M. Silica	51.1	0.0026	0.613	0.260					
-70 M. Silica	48.9	0.0059	1.314	0.631					
Total Silica	84.3	0.0042	1.927	0.891	0.024	0.005	0.008	0.012	0.05
Ore Feed	100.0	0.55							
Flot. Feed	86.5	0.56			0.170	0.460	0.020	0.040	0.05

Process	Conditions		pH	Reagents (lb per ton of ore)		
	Time (min)	% Solids		H ₂ SO ₄	TW-1197 TW-1158	Pamak 25
Belt Feeder	—	95				
Pulper	3.9	39				
#1 Pump	—	7				
#1 Cyclone U'flow	—	32				
Rod Mill	2	20				
Trommel Screen	—	—				
#2 Pump	—	3				
#2 Cyclone U'flow	—	12				
#1 Spiral Class.	6.0	70				
#3 Pump	—	10				
#3 Cyclone U'flow	—	19				
#2 Spiral Class.	6.0	70				
#1 Conditioner	5.1	58	2.04	1.0	—	—
#2 Conditioner	6.4	58	2.25	—	0.5	—
Flot. Cells	2.2	12	2.88	—	—	0.5

Remarks: Feed Rate—322 lb per hr (dry basis).

Water Used—13,405 gal per ton of ore.

Crowder plates removed from float cells for this and all subsequent tests.

* Heavy minerals.

† Refractory heavy minerals.

Table 2. Pilot Plant Test No. 4

Sample	Physical Data				Chemical Analysis, %				
	Wt %	% HM	g per 100 lb sand		Fe ₂ O ₃	Al ₂ O ₃	Na ₂ O	K ₂ O	LOI
+30 Mesh	2.0								
H.M. Float	9.3	5.59			0.88	0.84	—	—	—
-140 Slime	13.9								
+70 M. Silica	57.0	0.0016	0.424	0.082					
-70 M. Silica	43.0	0.0148	2.892	1.096					
Total Silica	74.8	0.0073	3.316	1.178	0.017	0.06	0.007	0.006	0.04
Ore Feed	100.0	0.52							
Flot. Feed	84.1	0.52			0.140	0.11	0.02	0.02	0.09

Process	Conditions		pH	Reagents (lb per ton of ore)		
	Time (min)	% Solids		H ₂ SO ₄	M-70	F-75
Belt Feeder	—	95				
Pulper	1.7	20				
#1 Pump	—	7				
#1 Cyclone U'flow	—	38				
Rod Mill	2.3	21				
Trommel Screen	—	—				
#2 Pump	—	3				
#2 Cyclone U'flow	—	14				
#1 Spiral Classifier	5.9	70				
#3 Pump	—	10				
#3 Cyclone U'flow	—	17				
#2 Spiral Classifier	5.9	70				
#1 Conditioner	6.3	61	1.77	2.5	—	—
#2 Conditioner	7.9	61	1.95	—	1.0	—
Flot. Cells	2.5	11	2.66	—	—	0.1

Remarks: Feed Rate—314 lb per hr (dry basis).

Water Used—12,983 gal per ton of ore.

* Heavy minerals.

† Refractory heavy minerals.

The silica produced in Test 5, Table 3, using Tex-Wet reagent alone, contained 0.527 g of +70-mesh refractory heavy minerals per 100 lb of sand; and the silica yield was 81.3%. The total content of refractory heavy minerals in the silica product was 0.849 g per 100 lb of sand.

The silica produced in Test 6, Table 4, in which a reduced amount of petroleum sulfonate was used with the Tex-Wet detergent-type reagent, contained 0.041 g of +70-mesh refractory heavy minerals per 100 lb of sand; and the silica yield was 83.2%. The total content of refractory heavy minerals in the silica product was 0.545 g per 100 lb of sand.

Test 7 involved a process similar to that of a commercial sand company in Camden, Tenn., in which fatty acid, sodium hydroxide, fuel oil, and pine oil are the reagents. Not only did the sand from this test not meet specifications, but the yield was by far the lowest obtained in the pilot plant experiments—62.9%. The test data are not included in the appendix.

The silica produced in Test 8, Table 5, in which the ore was scrubbed and Tex-Wet reagent used, contained 0.225 g of +70-mesh refractory heavy minerals per 100 lb of sand; and the silica yield was 77.0%. The total content of refractory

Table 3. Pilot Plant Test No. 5

Sample	Physical Data				Chemical Analysis, %				
	Wt %	% HM*	g per 100 lb sand		Fe ₂ O ₃	Al ₂ O ₃	Na ₂ O	K ₂ O	LOI
			HM*	RHM†					
+30 Mesh	3.8								
H M Float	1.5	22.8			4.10	1.23	—	—	—
-140 Slime	13.4								
+70 M. Silica	51.8	0.0073	1.722	0.527					
-70 M. Silica	48.2	0.0034	0.747	0.322					
Total Silica	81.3	0.0054	2.469	0.849	0.022	0.08	0.006	0.010	0.06
Ore Feed	100.0	0.35							
Flot. Feed	82.8	0.48			0.15	0.460	0.015	0.025	0.09
Process	Conditions				Reagents (lb per ton of ore)				
	Time (min)	% Solids	pH		H ₂ SO ₄			TW-1197	TW-1158
Belt Feeder	—	95							
Pulper	4.4	30							
#1 Pump	—	13							
#1 Cyclone U'flow	—	40							
Rod Mill	2.4	24							
Trommel Screen	—	—							
#2 Pump	—	4							
#2 Cyclone U'flow	—	20							
#1 Spiral Class.	5.5	70							
#3 Pump	—	10							
#3 Cyclone U'flow	—	19							
#2 Spiral Class.	5.5	70							
#1 Conditioner	5.4	60			1.8	1.0		1.0	
#2 Conditioner	6.7	60			1.9				
Flot. Cells	2.2	12			2.7				

Remarks: Feed Rate—338 lb per hr (dry basis).
 Water Used—11,877 gal per ton of ore.
 Collector reagent added to first pot in #1 conditioner.

* Heavy minerals.

† Refractory heavy minerals

Table 4. Pilot Plant Test No. 6

Sample	Physical Data				Chemical Analysis, %				
	Wt %	% HM*	g per 100 lb sand		Fe ₂ O ₃	Al ₂ O ₃	Na ₂ O	K ₂ O	LOI
			HM*	RHM†					
+30 Mesh	1.3								
H M Float	2.1	16.2			3.00	1.00	—	—	—
-140 Slime	13.4								
+70 M. Silica	57.9	0.0014	0.369	0.041					
-70 M. Silica	42.1	0.0064	1.226	0.504					
Total Silica	83.2	0.0035	1.595	0.545	0.023	0.07	0.005	0.007	0.11
Ore Feed	100.0	0.35							
Flot. Feed	85.3	0.43			0.16	0.50	0.02	0.04	0.24
Process	Conditions				Reagents (lb per ton of ore)				
	Time (min)	% Solids	pH		H ₂ SO ₄	M-70		TW-1197	TW-1158
Belt Feeder	—	95							
Pulper	2.7	35							
#1 Pump	—	9							
#1 Cyclone U'flow	—	37							
Rod Mill	1.9	23							
Trommel Screen	—	—							
#2 Pump	—	4							
#2 Cyclone U'flow	—	22							
#1 Spiral Class.	5.4	70							
#3 Pump	—	8							
#3 Cyclone U'flow	—	13							
#2 Spiral Class.	5.4	70							
#1 Conditioner	5.5	63		1.75	2.5				
#2 Conditioner	6.9	63		2.04					
Flot. Cells	2.3	13		2.47		0.5		0.5	

* Heavy minerals.

† Refractory heavy minerals

heavy minerals in the silica product was 1.177 g per 100 lb of sand.

The silica produced in Test 9, Table 6, using scrubbing and fatty acid with Tex-Wet reagent, contained 0.390 g of +70-mesh refractory heavy minerals per 100 lb of sand; and the silica yield was 84.5%. The total content of refractory heavy minerals in the silica product was 2.680 g per 100 lb of sand.

Test 10, using scrubbing and reduced amount of petroleum sulfonate and Tex-Wet reagent, produced sand which did not meet specifications. Data for this test are not given in the appendix.

Discussion

The petroleum sulfonate collector was used as a control because it had produced the best results in the previous sand beneficiation research at the Minerals Research Laboratory. The flotation process using this collector (Test 4) produced a silica product with next to the lowest amount of +70-mesh refractory heavy minerals, compared with other tests. The product yield for this test was the lowest (74.8%) of all of the tests, and the total content of refractory heavy minerals in the sample was next to the highest. With additional tests, yields

Table 5. Pilot Plant Test No. 8

Sample	Physical Data				Chemical Analysis, %				
	Wt %	% HM*	g per 100 lb sand		Fe ₂ O ₃	Al ₂ O ₃	Na ₂ O	K ₂ O	LOI
			HM*	RHM†					
+30 Mesh	3.6								
H M Float	6.3	5.39			0.88	0.398	—	—	—
-140 Slime	13.1								
+70 M Silica	55.4	0.0089	1.732	0.225					
-70 M Silica	44.6	0.0155	3.131	0.952					
Total Silica	77.0	0.0107	4.863	1.177	0.027	0.044	0.0062	0.0061	0.10
Ore Feed	100.0	0.357					0.0184	0.0312	0.12
Flot. Feed	83.3	0.369			0.114	0.41			
Conditions					Reagents (lb per ton of ore)				
Process	Time (min)	% Solids			H ₂ SO ₄		TW-1197 TW-1158		
Belt Feeder	—	—							
Pulper	—	—							
#1 Pump	—	—							
#1 Cyclone U'flow	—	—							
Rod Mill	—	—							
Trommel Screen	—	—							
#2 Pump	—	—							
#2 Cyclone U'flow	—	—							
#1 Spiral Classifier	—	—							
Scrubber	—	—							
#3 Pump	—	—				2.0			
#3 Cyclone U'flow	—	—							
#2 Spiral Classifier	—	—							
#1 Conditioner	—	—							
#2 Conditioner	—	—				1.0		1.0	
Flot. Cells	—	—							

* Heavy minerals

† Refractory heavy minerals

Table 6. Pilot Plant Test No. 9

Sample	Physical Data				Chemical Analysis, %				
	Wt %	% HM*	g per 100 lb sand		Fe ₂ O ₃	Al ₂ O ₃	Na ₂ O	K ₂ O	LOI
			HM*	RHM†					
+30 Mesh	2.4								
H M Float	2.0	18.8			3.50	0.80	—	—	—
-140 Slime	11.1								
+70 M Silica	48.6	0.0078	1.714	0.390					
-70 M Silica	51.4	0.0277	6.487	2.290					
Total Silica	84.5	0.0181	8.201	2.680	0.0270	0.039	0.0054	0.0034	0.04
Ore Feed	100.0	0.40							
Flot. Feed	86.5	0.44			0.17	0.398	0.0140	0.0184	0.15
Conditions					Reagents (lb per ton of ore)				
Process	Time (min)	% Solids	pH		H ₂ SO ₄	Pamak 25		TW-1197 TW-1158	
Belt Feeder	—	—							
Pulper	—	13							
#1 Pump	—	—							
#1 Cyclone U'flow	—	22							
Rod Mill	—	28							
Trommel Screen	—	—							
#2 Pump	—	—							
#2 Cyclone U'flow	—	15							
#1 Spiral Classifier	—	—							
Scrubber	—	70	3.2			2.0			
#3 Pump	—	—							
#3 Cyclone U'flow	—	—							
#2 Spiral Classifier	—	—							
#1 Conditioner	—	25	2.4						
#2 Conditioner	—	4			1.0		0.4		0.2
Flot. Cells	—	—							

Remarks: Feed Rate—294 lb per hr (dry basis).

Water Used—12.932 gal per ton of ore

* Heavy minerals.

† Refractory heavy minerals

in the 80% to 85% range probably could have been obtained with this heavy-minerals collector without exceeding the specifications for iron and refractory minerals in the product.

The flotation process using the anionic detergent-type collector in combination with petroleum sulfonate (Test 6) produced a product with a refractory-mineral content similar to that in the petroleum sulfonate test (0.041 vs. 0.082 g of +70 mesh refractory heavy minerals) but with higher (83.2% vs. 74.8%) yield. The total content of refractory heavy minerals in the sample was much less (0.545 vs. 1.178) than that of the test using petroleum sulfonate alone.

The chemical analyses of the products were approximately the same for all tests. The refractory heavy minerals contents of the total products varied from 0.545 to 2.680 g per 100 lb of sand.

One of the tests (Test 5) using the detergent-type reagent produced a product containing the largest amount (0.527 g per 100 lb of sand) of +70-mesh refractory heavy minerals; however, the amount of total refractory heavy minerals in the product was lower than that of the test using petroleum sulfonate. This would indicate that the process should be adjusted to float more coarse contaminants and thus reduce the

+70-mesh refractory heavy minerals in the silica product. Thus there were no significant differences apparent in the results obtained in the pilot plant using petroleum sulfonate collector and those obtained using the anionic detergent-type heavy-minerals collector. This indicates that equivalent results could be obtained with the two reagents in a commercial operation. At current market prices, the anionic detergent-type reagent would cost about 5¢ more per ton of silica produced than would petroleum sulfonate. However, the former is biodegradable while the latter is not. This could be a very important factor in helping to minimize stream pollution problems. With the fluctuating prices and the ever-changing availability of reagents, particularly the petrochemicals, it is good to have several alternatives for removal of contaminant minerals.

The modified commercial process utilizing fatty acid, sodium hydroxide, fuel oil, and pine oil was included because it had not been tested previously at the MRL. Under the conditions of these tests, this procedure was not satisfactory because the products did not meet specifications, and the yield was the lowest obtained.

The Tex-Wet detergent-type reagent produces a voluminous froth which appears excessive; however, the froth dissipates rapidly as observed in the pilot plant and in a commercial plant at Camden, Tenn., where this reagent was field tested. An absence of a good froth was experienced when using petroleum sulfonate or fatty acid (Pamak-25) as collector. However, a good froth was obtained by using the detergent-type reagent in combination with either of the other two reagents.

Under the conditions used, scrubbing was not required to produce silica meeting specifications. In fact, scrubbing seemed to have a detrimental effect.

A comparison of the analyses of MRL with L-O-F showed a slightly higher heavy minerals content for MRL. The MRL refractory heavy minerals content was lower for the +70 mesh fraction and higher for the -70 mesh fraction than L-O-F. The total refractory heavy minerals in the product was comparable between the two laboratories. Although the refractory heavy minerals content in the products were marginal or slightly higher than L-O-F specifications, the primary objective of comparing the effect of various reagents for removal of contaminant minerals was accomplished. L-O-F data is shown in Appendix D.

Conclusions

The following conclusions were reached:

- 1) Under the conditions of these tests, silica meeting chemical specifications for use in flat-glass production, and marginal as to limitations of +70-mesh refractory minerals can be produced by using a biodegradable anionic detergent-type collector for the heavy minerals.
- 2) In pilot plant operation, the above collector was nearly as effective alone and just as effective in combination with fatty acid or petroleum sulfonate, as petroleum sulfonate alone. Petroleum sulfonate was the best heavy-minerals collector found in previous sand beneficiation research at the MRL.
- 3) Under the conditions evaluated, scrubbing was not necessary and actually may produce undesirable effects.
- 4) The modified commercial process utilizing fatty acid, sodium hydroxide, fuel oil, and pine oil is not satisfactory under the conditions evaluated in this research.

Recommendation

It is likely that sand meeting specifications for use in flat-glass production could be produced by utilizing anionic detergent reagents if more extensive pilot plant tests were conducted. This is recommended if the use of rapidly biodegradable reagents becomes necessary.

Appendix A. Pilot Plant Test Data

Test 1: This test involved the use of crowder plates in flotation cells to assist in froth removal. No scrubbing was used. One pound of 66° Baume H_2SO_4 per ton of ore (added as a 5% acid solution) was added to the first conditioner. Two pounds of Tex-Wet reagent* per ton of ore were added to the second set of conditioners.

The product contained too much (5.46 g) +70-mesh refractory minerals. Detailed data for Test 1 are not given in this report.

Test 2: This test was similar to Test 1 except the collector was reduced to 1.0 lb per ton of ore and was added to the second set of conditioners instead of the first conditioners. The silica product was better than in the previous test but still contained too much (1.35 g) +70-mesh refractory minerals. Crowder plates may be detrimental, possibly causing bubbles to burst prematurely and release entrapped heavy minerals contaminants. The plates were removed before Test 3. Detailed data for Test 2 are not given in this report.

Test 3: One-half pound of fatty acid† and ½ lb of Tex-Wet 1158-1197 per ton of ore were added to the second set of conditioners. Sulfuric acid was added to the first conditioners. Crowder plates had been removed before this test. The silica contained 0.891 g of refractory minerals per 100 lbs of sand, with 0.260 g being in the +70-mesh fraction. Test 3 data are shown in Table 1.

Test 4: This was a commercial procedure which was included for comparative purposes. Two and one-half pounds of sulfuric acid per ton of ore were added to the first conditioners. One pound of petroleum sulfonate‡ and 0.10 lb of frother§ per ton of ore were added to the second conditioners. The silica product contained 1.178 g of refractory minerals per 100 lb of sand, with 0.082 g being in the +70-mesh fraction. Test 4 data are shown in Table 2.

Test 5: One pound of sulfuric acid and 1 lb of Tex-Wet 1158-1197* per ton of ore were added to the first conditioner. The silica product contained 0.849 g of refractory minerals per 10 lb of sand, with 0.527 g being in the +70-mesh fraction. Test 5 data are shown in Table 3.

Test 6: Two and one-half pounds of sulfuric acid per ton of ore were added to the first conditioner. One-half pound of petroleum sulfonate (M-70) and ½ lb of Tex-Wet 1158-1197 per ton of ore were added to the second conditioners. The silica product contained 0.545 grams of refractory minerals per 100 lb of sand, with 0.041 g being in the +70-mesh fraction. Detailed data for Test 6 are shown in Table 4.

Test 7: This test was intended to duplicate a processing technique used in a commercial sand plant in Tennessee, and it was included for comparative purposes. A satisfactory separation could not be made, and the float was difficult to control. The silica product contained an excessive amount of +70-mesh refractory minerals. Detailed data for Test 7 are not given in this report.

Test 8: An attrition scrubber was used in this test for additional cleaning of mineral grains for reagent attachment. Two pounds of sulfuric acid per ton of ore were fed to the scrubber. One pound of H_2SO_4 and 1 lb of Tex-Wet 1158-1197 were added to the first conditioner. The silica product contained 1.177 g of refractory minerals per 100 lb of sand, with

* This reagent consisted of a 5% solution of equally proportioned reagents obtained from Intex Products, Inc., Greenville, S.C.: TW-1158, sodium alcohol ether sulfate; and TW-1197, dodecylbenzene sulfonic acid.

† Pamak-25 obtained from Hercules, Inc., Wilmington, Del.

‡ M-70 obtained from Hunt Chemicals, Marion, N.C.

§ F-75 glycol frother obtained from American Cyanamid Co., Wayne, N.J.

0.225 g being in the +70-mesh fraction. Detailed data for Test 8 are shown in Table 5.

Test 9: An attrition scrubber was used in this test for additional cleaning of mineral grains for reagent attachment. Two pounds of sulfuric acid per ton of ore were fed to the scrubber. One pound of sulfuric acid, 0.4 lb of fatty acid (Pamak-25), and 0.2 lb of Tex-Wet 1158-1197 per ton of ore were added to the first conditioner. The silica product contained 2.680 g of refractory minerals per 100 lb of sand, with 0.390 g being in the +70-mesh fraction. Detailed data for Test 9 are shown in Table 6.

Test 10: An attrition scrubber was used in this test for additional cleaning of mineral grains for reagent attachment. A considerably reduced reagent charge was employed for this run. Two pounds of sulfuric acid per ton of ore were fed to the scrubber. One pound of sulfuric acid, 0.2 lb of petroleum sulfonate (M-70), and 0.2 lb of Tex-Wet 1158-1197 were added to the first conditioner. The silica product contained an excessive amount of +70-mesh refractory minerals. Detailed data for Test 10 are not given in this report.

Appendix B. Product Summary Data

Test No.	Reagent	Yield %	Total Heavy Minerals		+70 Mesh Heavy Minerals	
			g per 100 lb sand		g per 100 lb sand	
			HM*	RHM*	HM*	RHM*
3	Tex-Wet Pamak 25	84.3	1.927	0.891	0.613	0.260
4	M-70 F-75	74.8	3.316	1.178	0.424	0.082
5	Tex-Wet	81.3	2.469	0.849	1.722	0.527
6	M-70	83.2	1.595	0.545	0.369	0.041
8	Tex-Wet	77.0	4.863	1.177	1.732	0.225
9	Pamak 25 Tex-Wet	84.5	8.201	2.680	1.714	0.390

Test No.	% Fe ₂ O ₃	% Al ₂ O ₃	% Na ₂ O	% K ₂ O	% LOI
3	0.024	0.005	0.008	0.012	0.05
4	0.017	0.060	0.007	0.006	0.04
5	0.022	0.060	0.006	0.010	0.06
6	0.023	0.070	0.005	0.007	0.11
8	0.027	0.044	0.006	0.006	0.10
9	0.027	0.039	0.005	0.003	0.04

* Heavy minerals
† Refractory heavy minerals

Appendix C. Comparison of L-O-F and MRL Analysis (100 lb Sample Basis)

L-O-F Tests used 25 lb

MRL Tests used 2500 g or 5.51 lb

Test No.	Heavy Minerals Wt (Grams)				% Heavy Minerals			
	Untreated		Acid Treated		Untreated		Acid Treated	
	L-O-F	MRL	L-O-F	MRL	L-O-F	MRL	L-O-F	MRL
3	2.736	2.494	1.628	1.927	0.0060	0.0055	0.0036	0.0042
4	3.536	3.840	2.652	3.316	0.0078	0.0085	0.0058	0.0073
5	3.844	3.893	2.260	2.470	0.0085	0.0086	0.0050	0.0054
6	2.620	2.428	1.324	1.594	0.0058	0.0053	0.0029	0.0035
8	5.644	6.630	3.704	4.862	0.0124	0.0146	0.0082	0.0107
9	9.068	9.253	7.068	8.201	0.0200	0.0204	0.0156	0.0181

Refractory Content (g per 100 lb sand)

L-O-F Microscopic Analysis (Grain Count)

MRL Frantz Isodynamic Magnetic Separator and Microscopic Analysis (Grain Count)

Test No.	-40 Mesh		40 + 70 Mesh		Cum. +70		70 Mesh		Total	
	L-O-F	MRL	L-O-F	MRL	L-O-F	MRL	L-O-F	MRL	L-O-F	MRL
3	0.1372	—	0.4526	—	0.5898	0.260	0.5434	0.411	1.1332	0.891
4	—	—	—	—	—	0.082	—	1.096	—	1.178
5	—	—	—	—	—	0.527	—	0.322	—	0.849
6	0.0364	—	0.2464	—	0.2828	0.041	0.1059	0.504	0.3887	0.545
8	0.0300	—	0.5240	—	0.5540	0.225	0.4356	0.952	0.9896	1.177
9	0.0400	—	0.7120	—	0.7520	0.390	2.5670	2.290	3.3190	2.680

Model Sand Spec.: 0.200

Effects of Sand Surface Characteristics on Adhesion of Resinous Binders

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ABSTRACT

Adhesion to sand of organic binders modified with silane adhesion promoters is greatly improved if the sand surface is made more silica-like by acid treatment. Data is presented to show the benefits of using acid-treated sands with silanated versions of urethane cold box, furan hot box and alkyd-isocyanate, urethane or furan nobake binders. Types of acids and process variables such as temperature, contact time and concentration also were studied and appropriate data is presented. The mechanism by which sands are benefited by acid treatment is proposed to be related to removal of foreign ions from the sand surface. Chemical and physical properties of a variety of sands were measured and this data is discussed relative to the interactions of silane adhesion promoters on sand surfaces.

Introduction

Organic resinous binders are used extensively in the metal casting industry to make sand cores and molds. Normally, between one and two weight per cent binder is coated on sand to produce a flowable mix which can be blown or rammed in a pattern or core box. When this sand mix is hardened, either by thermal or cold curing techniques as required by the binder chemistry, tensile strength of 200-500 lb in.² (138 to 345 N/cm²) are usually attained. These core strengths depend primarily on the type and quantity of binder used but they are also influenced by other parameters, including physical and chemical properties of the sand grains and the atmospheric environment in which cores or molds are cured and aged.

Provided enough binder is used, cores and molds with more than adequate strength properties for foundry applications can be prepared with most sands. Significant benefits could result, however, if the interaction between binder and sand surface could be optimized to provide maximum bond strength and stability in extreme atmospheric environments. Possibly of most importance would be that binder levels could be minimized to effect cost savings and possibly alleviate the occurrence of binder-related casting defects such as those caused by gaseous degradation products or carbonaceous residues. Improved stability would eliminate core and mold scrap due to degradation when stored in moderate to high relative humidity environments and minimize the occurrence of abnormal casting defects resulting from the poor strength properties of humidity-degraded molds or cores. As defective castings are a major source of poor economy in the operating foundry, there would appear to be adequate incentives for striving to maximize the strength of the sand-binder interaction.

Most sands used as core and mold aggregates are natural minerals. Basically crystalline silica, specific compositions and mineral morphology of sands vary with their source, as these properties are determined by geological factors. In the Great Lakes regions, where a major portion of the domestic foundry industry is located, lake sands are plentiful and can be supplied to foundries at attractive costs. These sands typically have silica contents in the range from 90-98% with the remainder being composed of the oxides of aluminum, iron, titanium, calcium, magnesium and the alkali metals. These impurity elements

always are associated with oxygen and may be present in complex mineralogical structures which can vary depending on the source of the mineral.

For foundry applications, many sands are processed by simple drying, while others may be washed to eliminate clay and organic matter before drying. Flotation agents sometimes are used for separation of undesirable mineral constituents. Considering the multitude of sand sources and the straightforward processing techniques currently practiced, it is not surprising that the foundryman encounters a wide range of performance in his core and molding operations which are dependent on sand, as well as binder parameters.

These differing performance characteristics often result from differences in the adhesive strength of the sand-binder interaction. In order to optimize this adhesive interaction, both binder and sand properties must be considered. The use of silane adhesion promoters as binder modifiers has been a relatively recent advancement towards improving adhesion at the sand-binder interface, although their use for improving adhesion of resins on a variety of mineral surfaces is well known. Nevertheless, silanes are still used sparingly in foundry binders as they are ineffective in some systems and in others provide benefits which are strongly dependent on the particular sand being used. Thus, it would be of significant value to delineate the characteristics of sands which exert controlling influence on the strengths of sand-binder interactions and the effectiveness of silane adhesion promoters.

Based on these considerations, a program was initiated with the ultimate objective of developing practical techniques for modifying sand surfaces to promote improved adhesion of foundry binders. Although a number of techniques have been investigated and others are currently being studied, one approach evolved from the knowledge that very high purity silica sands generally provide the best strength performance with foundry binders, especially those modified with adhesion promoters. Phenomenologically, this suggests that maximum adhesion in sand-binder systems results when the sand surface has the most silica-like character. Consequently, it was expected that by removing alien ions, a more silica-like sand surface would result and provide the improved performance characteristics which were sought. Following this reasoning, acid treatments of sands were investigated as a means for beneficiating the sand surface. The effects on core performance, using standard binders with and without modification with silane adhesion promoters, were measured. In all cases where silane adhesion promoters were employed, these were added to the binders at the level of 0.5 wt. %. The particular silane employed was an amino-functional type¹ although independent studies have shown other types to perform equally well.

How Binder Type Determines Core Strength Characteristics

Core strength characteristics using a variety of binders on a typical lake sand, Fig. 1, illustrate how strength levels vary with the nature of the binder and the storage humidity environment. The six binders chosen for the data of Fig. 1 illustrate types used in nobake, cold box and hot box coremaking processes and are fully representative of binder systems available to the foundry industry. Essentially all resin-bonded sand systems experience strength degradation when exposed to high relative humidity conditions.

For the measurements, tensile specimens were prepared using the appropriate core process. All sand-binder mixes were prepared with the aid of a paddle mixer using standard mixing times. Cold box and hot box cores were blown while nobake cores were hand rammed in 12-cavity ganged boxes to avoid bench life effects. All cores were allowed to cure fully over a 24-hour period in the ambient environment (approximately 75% and 30% relative humidity) and then were placed in chambers at various relative humidities and allowed to age in this environment at 75% for a period of 24 hours. Specimens removed from the test chambers were tested immediately to measure tensile strength.

Conditioning core specimens for this 24-hr period realizes the full

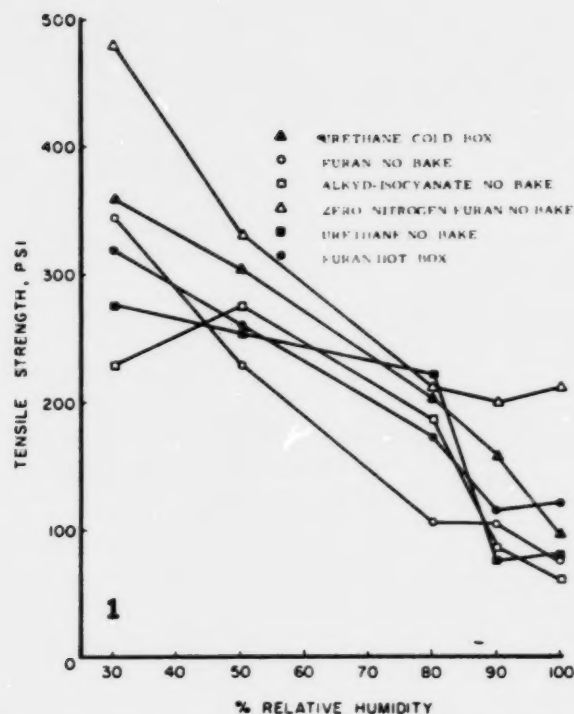


Fig. 1 Performance of foundry binders on Sand A at 2% binder level.

effects of humidity on core degradation and provides delineation of the relative performance characteristics of different binders. The data shows that core degradation increases with increasing relative humidity in the storage environment regardless of the type of binder employed. At low relative humidities, core strengths at the 2% binder level range from a low of about 225 lb in.² (155 N cm²) to a high near 500 lb in.² (345 N cm²). At 100% relative humidity, core strengths fall within the range from 60 to 120 lb in.² (41 to 83 N cm²), with the exception of zero-nitrogen furan nobake which is a binder specifically designed to give improved performance. In terms of percentage of strength lost, these values indicate that as much as 80% of core tensile strength can be degraded in severe environmental humidity conditions.

Experience has shown that other commercial binders available to the foundryman behave in similar manner when subjected to these test conditions. Although data were obtained using Sand A*, a washed and dried aggregate typical of lake sands used in foundries, similar results are obtained with high purity silica sands. Generally, however, strength levels using high purity silica sands are slightly higher and in certain cases abnormally good performance may be obtained when using high performance binders such as the zero-nitrogen furan nobake. With sands of lower purity (e.g., some bank sands) strength characteristics of core systems are generally lower than with lake sands, but the trends of decreasing strength with increasing relative humidity are still found.

Improving Sand Performance by Acid Treatment

Response with Cold Box Binders — Acid-treating of sand consists of bringing it in contact with aqueous acid for a period of time, then washing to remove all excess acid and drying. Typically, sulfuric acid provides an effective treatment but other acids may be used and these aspects of the process (as well as consideration of time and temperature parameters) are discussed later. Figure 2 shows a comparison of strength properties at various storage humidities for cores prepared with both untreated and modified Sand A bonded with the urethane cold box binder. Figure 2 also shows strength vs relative humidity performance

*See Tables 2 and 3 for screen distribution and properties of sands referred to in text.

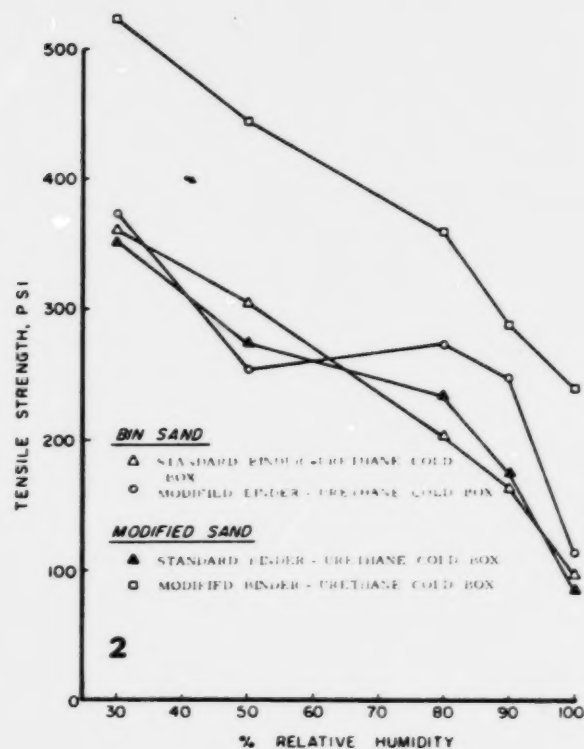


Fig. 2 Comparison of bin and modified Sand A using cold box binder at 2% binder level.

for cores prepared using these sands bonded with a silane-modified version of the urethane cold box binder.

With the unmodified binder, strength improvements of 25-30% result from use of the acid-modified sand as compared to performance with untreated sand. Comparing performance on untreated sand, the modified binder provides a modest improvement in performance over that obtained with the unmodified system. This improved performance is to a level approximating that obtained by use of acid-treated sand bonded with the unmodified binder.

Combining acid-treated sand with modified binder, much greater improvements in strength performance are obtained. This combination provides a 68% improvement in strength at the lowest humidity and a 300% improvement at the highest humidity when compared to results obtained with unmodified sand bonded with unmodified binder. Possibly of most significance in these results is the fact that the improved system shows excellent resistance to strength degradation at high test humidity levels. Thus, cores made with the modified binder and acid-treated sand should provide excellent storage properties, even at extreme levels of environmental humidity.

In order to be certain that the effects of acid processing of sand are not simply the result of contact with water, control experiments were carried out to compare performance of untreated, acid-modified, and water-treated Sand A bonded with the modified cold box binder. Results of these experiments, Fig. 4, show performance of sands treated in various ways and bonded with the modified cold box binder. Three methods were examined: 1) soaking the sand in cold 10% sulfuric acid solution for 24 hours followed by washing and drying; 2) soaking the sand for 24 hours in hot 10% sulfuric acid followed by washing and drying; and 3) coating sand with 5 pph** of cold 10% sulfuric acid, allowing this mix to age for seven days and then washing and drying. For comparison, core performance using the untreated sand is included.

Each of these methods of acid treatment is effective in upgrading the performance of Sand A bonded with a silanated cold box binder. In the

**Parts per hundred.

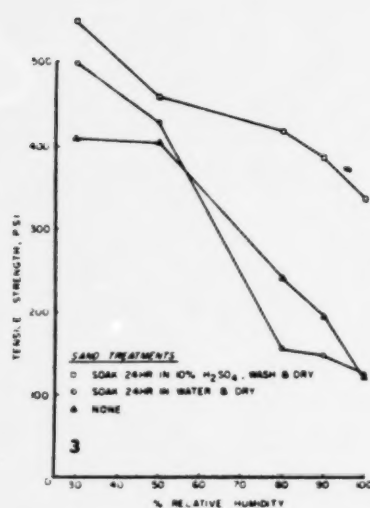


Fig. 3. Comparison of acid and water treatments of Sand A using 2% modified cold box binder.

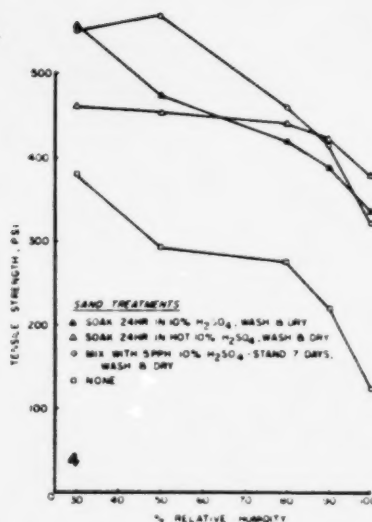


Fig. 4. Comparison of various acid treatments of Sand A using 2% modified cold box binder.

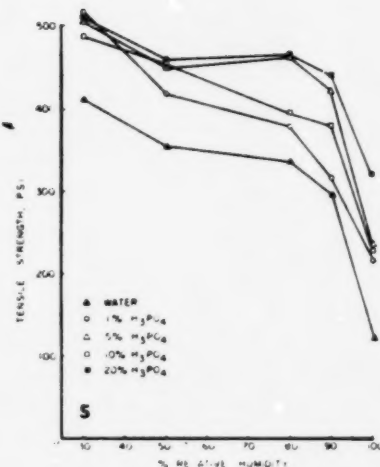


Fig. 5. Effect of acid concentration using soak treatment at 2% modified cold box binder on Sand A.

high humidity test range, no particular advantage was found for any one of the treatment techniques, as all provided approximately the same performance benefits. In the lower test humidity range, treatment with hot acid appeared to be somewhat less effective than the cold treatments which was surprising, as the hot treatment could be expected to offer some advantage over a cold process by promoting faster conversion of the sand surface to a silica-like character.

Other moderately strong inorganic and organic acids have been found to be equally effective for sand modification. In particular, sulfuric, hydrochloric, phosphoric and p-toluene sulfonic acids have all been found to provide approximately equal benefits in the sand modification process. Acetic acid was not effective, presumably being too weak an acid to effect the changes necessary on the sand surface.

Effect of Acid Concentration The effect of varying acid concentration was determined both for the *cold soak* and the *mix and age* procedures. For the soak method, phosphoric acid was used at 1, 5, 10 and 20% concentrations in a procedure wherein the sand was soaked for 24 hours

in the acid solution and then washed and dried. Results of these experiments are shown in Fig. 5 together with performance data for Sand A which was soaked for 24 hours in water and then dried. These results indicate that the preferred acid concentration is at least 20%, since this level provided the maximum performance in core strength at the 100% relative humidity test. Since reactions taking place at the sand surface are rate processes, it could be expected that lower acid concentrations would be equally effective provided longer soak periods or higher temperatures were employed.

Figure 6 shows the results of the mix and age experiments. In each test, Sand A was mixed with 5 pph of acid and this mix was allowed to age for seven days after which it was washed and dried. Three different acid concentrations were used. At the lowest, concentrated sulfuric acid was diluted with 9 volumes of water to yield a solution approximately 14 Baumé, while the highest concentration the acid was diluted with an equal volume of water. To a first approximation, each of these acid concentrations provided approximately the same benefits in improved sand performance in the strength versus relative humidity tests.

Effect of Contact Time For the *soak* treatment using 10% sulfuric acid, a minimum contact time of four hours was necessary for maximum performance of the treated sand. To determine the effect of contact time in the *mix and age* method, experiments were carried out using Sand B mixed with 5 pph of 10% sulfuric acid and allowed to age for a total of 168 hours. Samples of this sand-acid mix were taken after the first 24-hour aging period and again after 72 hours, 120 hours and at the end of the 168-hour aging period. These sand samples were washed free of excess acid and dried at 400°F (204°C).

Core performances of the 24, 72 and 168-hour samples were determined using the modified cold box binder while the 120-hour sample was tested with the standard cold box binder for comparison. Results of these tests, Fig. 7, show that the 24-hour aging period provided essentially full improvement in sand performance; further improvements accruing from the 72-hour or 168-hour aging times were very slight or negligible. Also, it may be noted that the sand aged for the full 120-hour period showed little improvement in performance when bonded with the standard binder.

Response of Various Sands Although a limited number of sands have been studied with regard to response in the acid treatment, enough positive results have been obtained to indicate that the modification process should be applicable to most sands normally encountered in foundry operations. Results obtained using ten sands, including lake, bank and silica sands, are tabulated in Table I. These data show the performance advantages resulting from the use of acid-treated sands bonded with silane-modified cold box binder. Performance im-

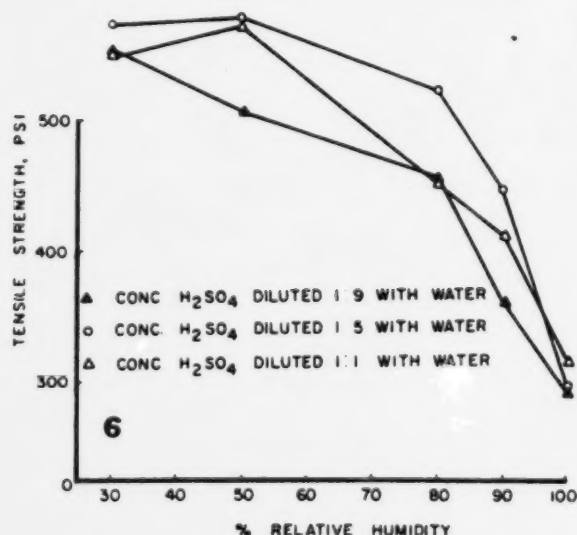


Fig. 6. Effect of acid concentration using mix and age treatments at 2% modified cold box binder.

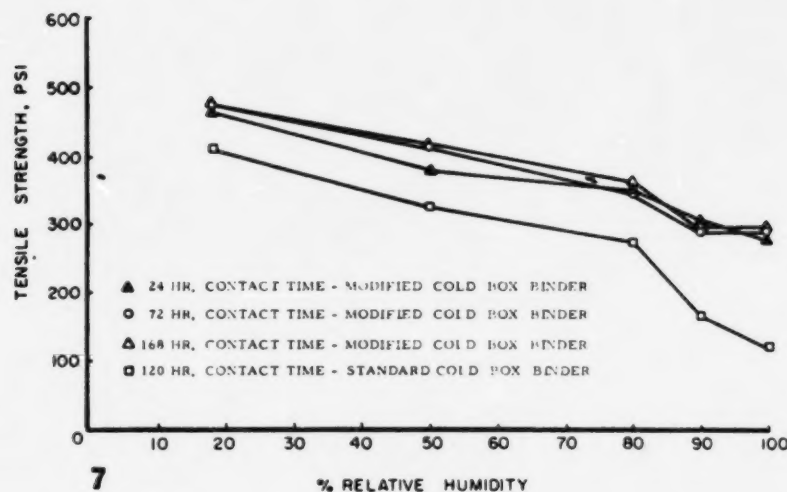


Fig 7. Effect of contact time on efficiency of acid treatment at 2% binder level. Sand B mixed with 5 pph of 10% H_2SO_4 . After test contact time, sand washed free of excess acid and dried at 425F (218C).

provements are greatest in the high humidity test, as evidenced by the data in the last column. In most cases, improvements were obtained over the full range of test humidities, but results varied widely from sand to sand. In some cases, the benefit from use of acid-modified sands was only in the better resistance to strength degradation at higher test humidity.

It is of interest to note that Sand F, which is 99.8% silica, responds nicely to the silane-modified binder. This is presumed due to the high purity nature of this sand and suggests that the effect of the acid treatment is to produce a more silica-like surface. Even Sand F, however, is beneficiated via the acid-treatment process, as substantial improvements in core performance result at both low and high test humidities.

Included also in Table I are results obtained with Sand J and Sand K. These sands are low-silica materials and provide inherently poorer bondability by resinous binders. They nevertheless do respond to the acid-treatment, as shown particularly by core strength results at high test humidity. Because of higher impurity levels, it may be more difficult to convert bank sand surfaces to silica-like character by cold acid treatments, and longer contact times or higher temperatures may be necessary for substantial beneficiation by acid treatment.

Response with Other Binders Advantages of acid-treated sands are not limited to applications employing modified cold box binders but are obtained also with a wide range of core binders commonly used in the foundry. Figures 8 through 12 illustrate the advantages of modified sands when bonded with urethane, oil-modified urethane and furan nobakes and with a furan hot box binder. With the exception of the zero-nitrogen furan nobake binder, which requires no modification for improved performance on acid-treated sand, maximum benefits from the treated sands are derived in each case by use of silane-modified binders. For example, the data of Fig. 8 shows that small improvements result from use of untreated Sand A bonded with modified urethane nobake binder, or from the use of acid-treated sand bonded with the unmodified binder, but significantly greater improvements result by combining acid-modified sand with silane-modified binder.

Similar performance characteristics were found in use of the furan nobake and furan hot box binders. With the alkyd-isocyanate nobake binder, improvements were observed primarily in the high humidity test and although these were relatively small, they could have significant consequences for certain foundry operations. Figure 12 shows the performance of the zero-nitrogen furan nobake on Sand A treated with either sulfuric, hydrochloric or phosphoric acids. Each of these acid treatments provides performance significantly improved relative to that using unmodified sand.

TABLE 1. - Response of Various Sands to Acid Modification

Sand	Acid * Modification	Urethane Box Binder	Cold Binder	Tensile Strength, psi, after 24 hr. at test relative humidity				
				40%	50%	80%	90%	100%
A	None	Std.		360	308	203	163	91
	None	Mod.		373	255	272	247	113
	Yes	Std.		353	273	234	171	84
	Yes	Mod.		523	443	363	287	238
B	None	Std.		398	382	195	154	143
	None	Mod.		360	358	298	129	120
	Yes	Std.		416	416	256	185	118
	Yes	Mod.		451	471	357	276	267
C	None	Std.		394	344	202	125	122
	Yes	Std.		374	395	258	193	147
	Yes	Mod.		462	446	337	276	227
D	None	Std.		424	425	226	140	110
	Yes	Std.		432	434	248	209	133
	Yes	Mod.		450	485	391	303	209
E	None	Std.		386	373	247	196	124
	None	Mod.		396	363	324	265	182
	Yes	Std.		520	496	239	154	120
	Yes	Mod.		597	659	431	400	266
F	None	Std.		382	323	283	149	108
	None	Mod.		395	375	380	430	288
	Yes	Mod.		511	423	380	448	339
	Yes	Mod.		342	330	260	122	85
G	None	Std.		268	278	160	83	63
	None	Mod.		363	355	295	207	123
	Yes	Std.		353	327	173	108	95
	Yes	Mod.		422	412	367	320	262
H	None	Std.		142	130	107	87	53
	None	Mod.		187	162	168	157	108
	Yes	Std.		165	168	122	87	65
	Yes	Mod.		212	213	167	165	142
J	None	Std.		208	193	143	110	87
	None	Mod.		192	183	142	117	92
	Yes	Std.		203	198	132	98	62
	Yes	Mod.		203	218	168	168	128
K	None	Std.		323	247	178	98	97
	None	Mod.		338	262	197	148	120
	Yes	Std.		337	273	227	177	185
	Yes	Mod.		345	292	227	214	185

* By soaking in cold 10% sulfuric acid

Process Considerations — Commercial utilization of an acid-treating sand modification process appears feasible employing either a hot acid leach or the *mix and age* method. Cold soaking procedures are effective in laboratory operations but the time requirements necessary in the acid leach step would seem to prohibit large volume production of acid-modified sand in this manner. If hot acid were employed, this leach time could be drastically shortened. Some sand suppliers currently use hot acid-leaching processes for supplying sands suitable for glass manufacture, where the primary requirement is low iron content. Tests with some of the commercial acid-treated sands indicate that performance benefits equivalent to that obtained with lab-processed sands are obtained when bonded with silane-modified binders.

A simple and conceptually straightforward technique for acid-modifying sand is the *mix and age* method. It appears feasible to mix sand with 5 pph of 14° Baumé sulfuric acid and set aside in aging pits for one week or longer. It would be necessary to protect the aging sand-acid mix from the weather, as rain water could wash away the acid and terminate the leaching reactions which are necessary to gain benefit from the process. After an aging period of one week or longer, sand could then be brought back into the plant for washing and drying using normal sand plant equipment and procedures.

If phenolic-urethane or alkyl-isocyanate binders are to be used, it is absolutely essential that the treated sand be washed free of all excess acid, as essentially all benefits from the acid treatment may be lost if the final product contains excess acid. A tentative specification derived from laboratory studies would be that the completely processed sand should provide a pH greater than 6.5 when slurried with water.

Properties of Acid-Treated Sands

In an attempt to delineate the chemical or physical changes occurring during acid-treatment, measurements were made of screen distributions, surface areas, water content and elemental content of several sands before and after acid treatment. These same sands were examined also using the scanning electron microscope in the expectation of observing physical changes which could be correlated with other physical (and chemical) measurements and performance in bonded systems.

Screen distributions were altered only slightly by the acid treatment process, Table 2. This was expected as care was taken in the laboratory processing not to lose appreciable amounts of material, although during

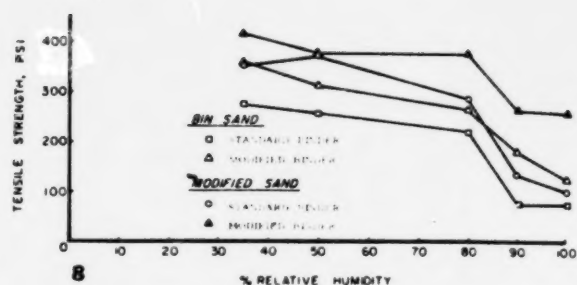


Fig. 8. Performance of urethane nobake on Sand A at 2% binder level.

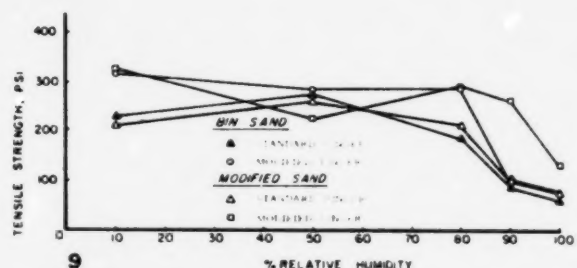


Fig. 9. Performance of alkyl-isocyanate nobake on Sand A at 2% binder level.

the cold acid-soak treatments, scum which floated to the surface of the acid solution was subsequently separated in the water washing stage. This scum represents the very fine particle content of the sand, particularly the pan fraction in the sieve analysis, as can be seen by inspection of the screen distribution data. Although all of the sands, with the exception of Sand F, were quite low in fines content, the acid-treatment was effective in reducing even further the content of very fine material. These changes, however, were quite small and resulted in minor changes in the calculated grain fineness No. (phi) classification of the sands. For Sand F, which contained appreciable quantities of +200 and pan fractions, the effectiveness of acid treatment in removing fines

TABLE 2. - Screen Distributions of Sands

Screen	Sand A		Sand B		Sand C		Sand D		Sand E		Sand F	
	Orig.	Treated	Orig.	Treated	Orig.	Treated	Orig.	Treated	Orig.	Treated	Orig.	Treated
30	0.9	0.6	0.07	0.01	0.3	0.3	0.9	0.9	0.2	0.2	0.2	0.2
40	6.9	5.9	3.1	2.4	4.0	3.9	4.8	4.9	2.6	2.4	7.5	7.5
50	39.1	28.6	23.6	23.8	24.5	25.7	24.1	25.4	21.9	21.4	44.5	41.2
70	39.4	40.1	27.6	27.8	58.0	58.2	46.7	47.3	62.1	62.4	34.2	35.5
100	19.0	20.8	23.0	24.6	12.9	11.4	19.6	18.0	12.9	13.4	11.4	12.3
140	2.9	3.2	15.7	16.3	0.1	0.4	2.8	2.8	0.3	0.2	1.6	1.7
200	0.6	0.7	4.5	4.9	0.1	0.06	1.0	0.7	0.03	0.003	0.5	0.4
270	0.05	0.06	0.2	0.2	0.003	0.017	0.1	0.1	N. I.	0.003	0.05	0.03
Pan	0.04	0.007	0.2	0.003	0.007	0.007	0.05	0.003	0.003	0.003	0.05	0.01
GFN	51	52	64	65	49	49	55	52	50	50	48	48
Geometric Surface Area, cm ² /g	87	90	110	112	84	84	95	90	86	86	82	82
BET Surface Area, cm ² /g	3500	6400	4300	2700	4300	8600	4500	8900	4000	8300	4300	9800
Roughness Factor BET/Geom.	40	71	39	24	51	102	47	99	47	96	52	119

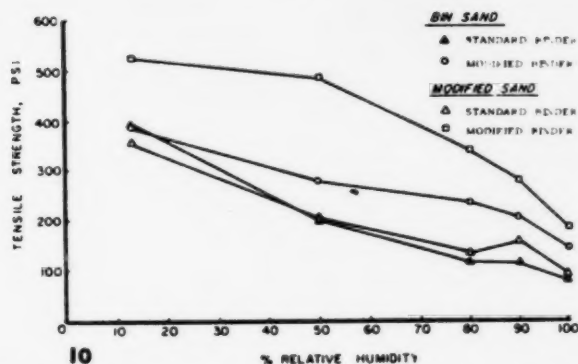


Fig. 10. Performance of furan nobake on Sand A at 2% binder level.

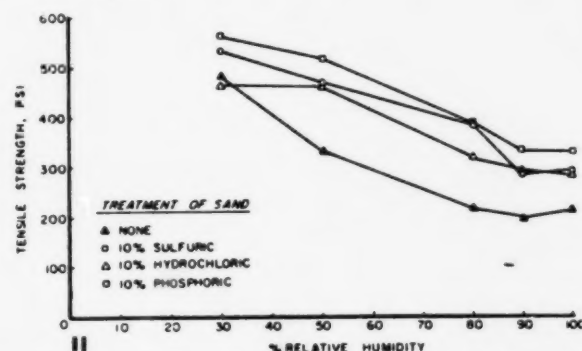


Fig. 11. Performance of zero nitrogen furan nobake on Sand A at 2% binder level.

was more evident in the screen analysis although the effect on η_{in} was small.

Surface areas were measured using the BEI technique¹ and then compared to calculated geometric values based on screen distribution and a spherical particle model. Acid-treatment of sand, Table 2, generally resulted in approximately a 100% increase of the BEI surface area. Since screen distributions change little, the changes in calculated geometric surface areas are insignificant. Thus, acid-treatment of sand must cause physical changes, such as etching at the sand surface which exposes a greater number of surface atoms. Roughness factors calculated as the ratio of BEI surface to calculated geometric surface were also calculated.

TABLE 3. - Properties of Sands

	Sand 1		Sand 2		Sand 3		Sand 4		Sand 5		Sand 6	
	Orig.	Treated	Orig.	Treated	Orig.	Treated	Orig.	Treated	Orig.	Treated	Orig.	Treated
SiO_2	94.19	94.49	99.27	99.68	93.53	94.14	93.49	93.86	92.90	93.49	94.04	92.00
Fe_2O_3	0.35	0.27	0.04	0.02	0.44	0.31	0.48	0.53	0.42	0.32	0.20	0.14
Al_2O_3	2.50	2.55	0.35	0.10	2.85	2.80	2.80	2.75	2.85	2.80	5.05	5.10
TiO_2	0.04	0.04	0.05	0.03	0.05	0.05	0.07	0.11	0.05	0.05	0.02	0.02
CaO	0.32	0.28	0.01	0.02	0.49	0.37	0.48	0.35	0.53	0.38	0.33	0.31
MnO (ppm)	240	120	0.01 ⁴	0.01 ⁴	380	190	480	190	420	140	75	75
K_2O	1.16	1.26	0.05	0.04	1.19	1.18	1.26	1.26	1.74	1.73	1.26	1.27
Na_2O	0.19	0.24	0.01	0.01	0.34	0.36	0.27	0.30	0.34	0.34	0.45	0.44
Loss on Ign.	0.24	0.11	0.18	0.09	0.45	0.15	0.42	0.14	0.51	0.14	0.10	0.16
Surface Area m^2/g	.35	.64	.43	.27	.43	.86	.45	.89	.40	.83	.43	.98
Water, u/o	0.03	0.02	0.02	0.01	0.03	0.02	0.01	0.02	0.03	0.02	0.04	0.05

1. analyses by X-ray fluorescence spectroscopy except for Fe and Mn which were determined by emission.

2. SiO_2 determination.

3. Karl-Fischer Titration. Sand equilibrated at 70% and 50% relative humidity for 3 days.

4. analysis by X-ray fluorescence.

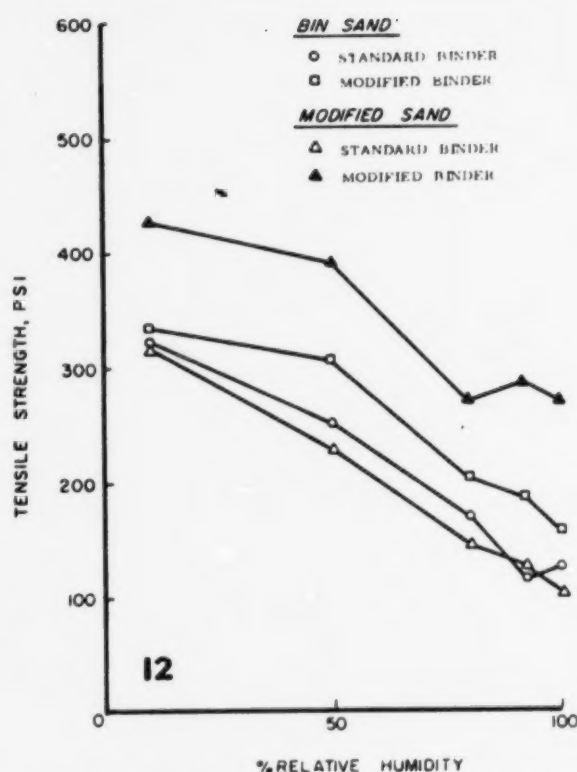


Fig. 12. Performance of furan hot box on Sand A at 2% binder level.

The single exception to an increased BEI surface area due to acid-treatment occurred with Sand 1. In this case the measured surface area after treatment was less than before, which seems most probably the result of removal of the appreciable pan fraction which would contribute significantly to the total surface area of the sample. It could be argued also that since pan fractions were reduced during acid treatment of the other sands, the true changes in surface area due to this processing are somewhat greater than reflected by the BEI measurements.

Results of chemical analyses are tabulated in Table 3. A small but consistent increase in silica content resulting from acid treatment suggests that the processing removes foreign elements from the sand.

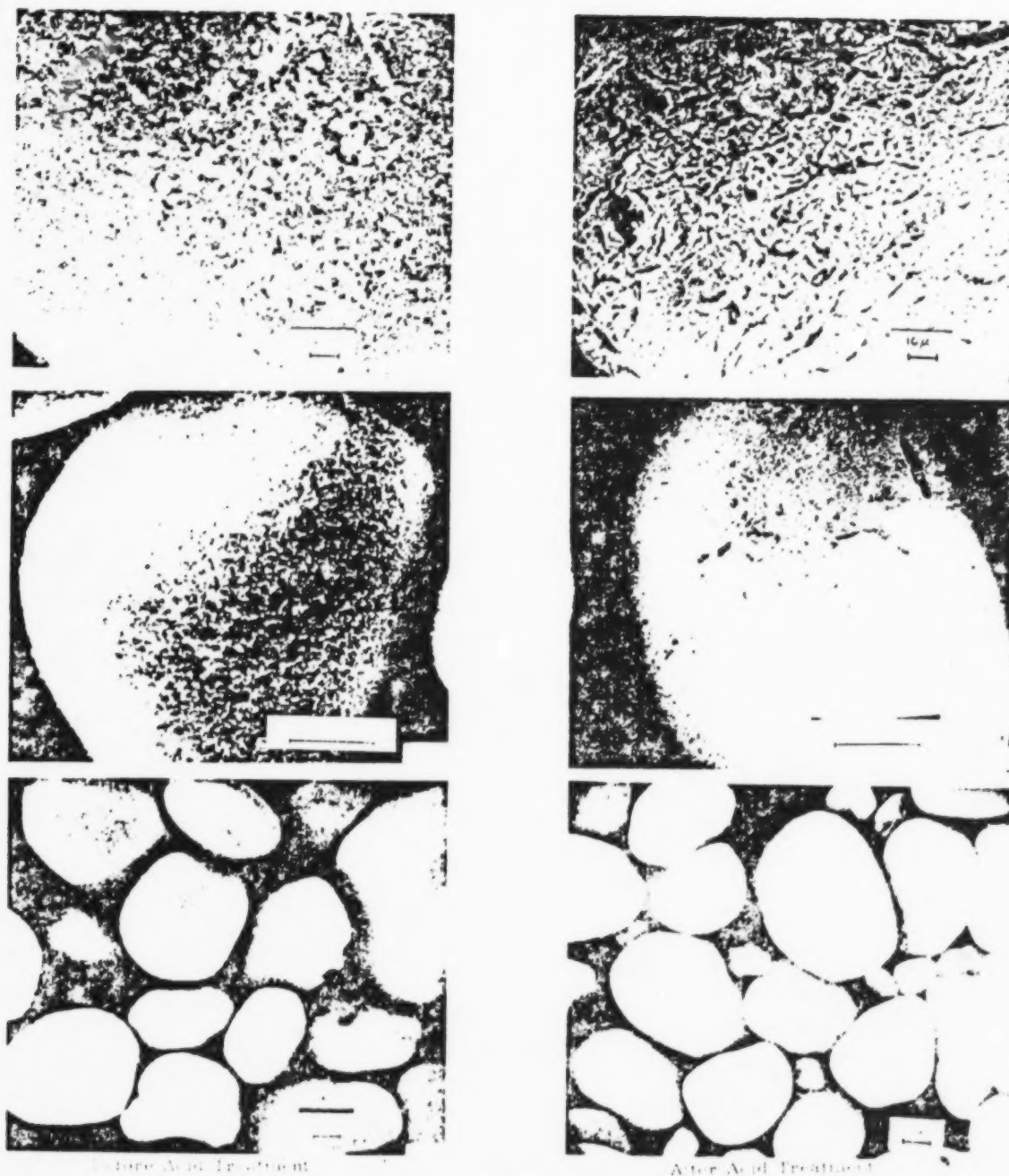


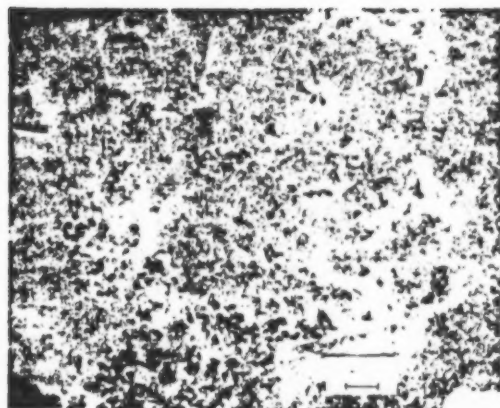
Fig. 13. Scanning electron photomicrographs of original and acid-treated Sand E.

surface. The small changes in contents of impurity atoms such as Al, Fe, Ca, Mg, K and Na show that these elements are not completely removed from the sand structure although, of course, the data on bulk composition cannot be used to deduce changes in the surface composition. Indeed, a calculation using an average BET surface area indicates that the outermost 10 Å surface layer of a sand grain comprises less than 10% of the total grain volume.

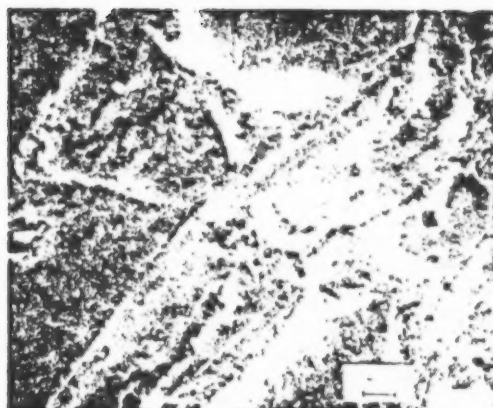
Thus, changes in impurity atom content due to acid treatment should be of the order of 10%, provided these impurity atoms are homogeneously distributed. If impurity elements are concentrated on the grain surfaces or in the interior bulk of the grains, either larger or smaller composition changes would result. The analytical data confirms, in general, that impurity elements are removed from sand surfaces

by acid treatments, but detailed knowledge of specific surface compositional effects still remains obscure because results varied widely from sand to sand.

Moisture determinations on sands preconditioned at 70% (21°C) and 50% relative humidity, Table 3, suggest a trend towards lower affinity for water among acid-treated sands; however, some exceptions were noted. Since acid treatment increases surface area it might be predicted that processed sands should exhibit higher equilibrium water absorption characteristics. On the other hand, alkali and alkaline earth ions, which have strong affinities for water, should be readily removable from sand surfaces by acid treatment. Etching of these ions is thought to be responsible for the lessened affinity of the treated sands for adsorbed water.



Before Acid Treatment



After Acid Treatment

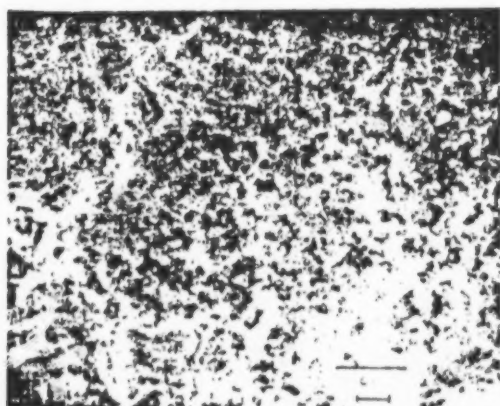


Fig. 14. Scanning electron photomicrographs of original and acid-treated Sand C.

Examination in the scanning electron microscope clearly revealed the efficiency of acid treatment in removing very fine particle clay and other matter from the sand surface. Figure 13, comparing micrographs at 60X, 180X and 600X of the original and acid-treated Sand E, illustrates efficient removal of fines by acid treatment. Micrographs (Fig. 14) of Sand C before and after acid treatment, show similar effects—less obvious, since this sand contained a smaller fraction of fines before acid treatment. Comparison of the other sands in the scanning electron microscope provided information similar to that for Sand C.

Attempts to detect evidence of surface etching were inconclusive. At magnifications of 180X or lower, surface details are not resolved adequately to show evidence of etching and at the higher magnifications it is difficult to deduce representative surface features since only a portion of the surface of an individual sand grain can be examined at one time. Subjective interpretations of the photomicrographic examinations, however, did lead to the conclusion that surface etching results from acid treatment.

Discussion

The most important phenomenological effect of acid treating a foundry sand is the enhanced strength performance and humidity resistance obtained in using binders containing silane adhesion promoters for core or mold preparation. Acid treatment alters the sand surface in such a manner that the silane adhesion promoter becomes more effective. This could be the result of removing sites which provide water-sensitive interactions with silanes or removing sites which are effective scavengers for silanes. Other phenomena may be dominating, so that the actual mechanism responsible for improved efficiency of silane adhesion promoters is open to speculation.

Although high purity sands, such as Sand E and Sand F are benefited by acid treatment with regard to response with silanated

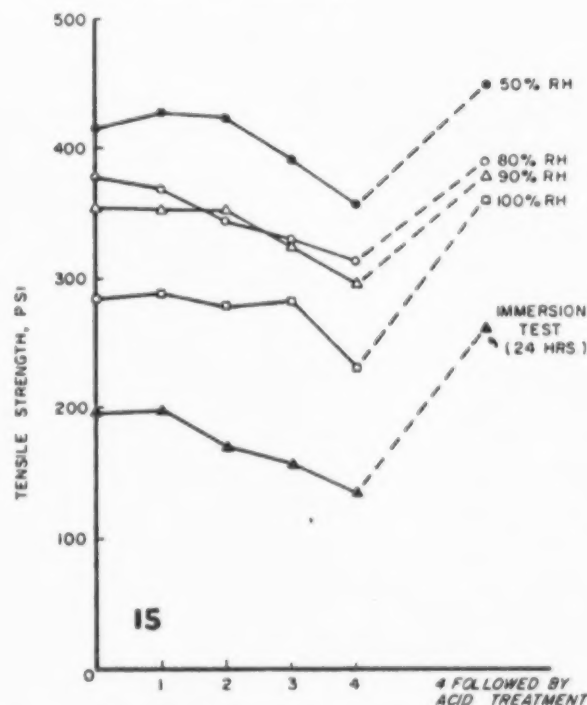


Fig. 15. Effect of alkaline treatment of Sand F at 2% modified cold box binder level.

binders, their performance without the acid modification is substantially better than that of untreated lake or bank sands, which are lower purity materials. These facts support the contention that sand impurities provide surface sites which somehow prohibit the type of interaction between silane and sand surface which is necessary for adhesion promotion.

Lake and bank sands contain small amounts of fine particle material, probably clays, adhering to the grain surfaces. SEM micrographs show this fine material to be intermittently dispersed on the surface. Generally, the presence of fine particles would adversely affect binder adhesion by providing a weakly bound intermediate layer between sand surface and binder. Silane adhesion promoters, however, should still be effective unless preferentially scavenged by adsorption or chemical reaction with the clay-like material, thereby depleting the presence of silanes at more effective sites on the sand surface.

Acid treatment of sands increases BET surface area and therefore provides a greater area of the sand binder interface per unit cross sectional area in a core or mold composite. An increased adhesive force per unit cross sectional area could lead to increased core or mold strength. However, surface area cannot be the dominant factor controlling binder adhesion, and therefore core mold strengths (because Sand F, although having a BET surface area of only 1300 cm²/g, provides higher core strengths than lake sands with 3000-4500 cm²/g surface areas. Moreover, when these lake sands are acid treated they provide performance with silanated binders which is approximately equivalent to that obtained with Sand F even though surface areas of the treated sands range from four to seven times that of Sand F. It is concluded that better adhesion characteristics obtained with acid-treated sands cannot be the result of increased surface areas.)

These considerations lead to the speculation that chemical effects exert a dominant role in controlling interactions of sand surfaces with silanated binder systems. Foreign ions on the sand surface could hinder silane effectiveness by preferential scavenging of the adhesion promoter, thereby resulting in interactions more susceptible to humidity degradation than the interactions of a silane with a silica surface sites.

Since much of the consequence of ineffective silane interaction with the sand surface manifests itself in poor resistance to humidity degradation, it can be suggested that foreign ions having high affinities for water interfere with the normal mechanism of silane adhesion promotion. The most likely foreign ions to consider in this regard would be the alkalis, sodium and potassium, and to a lesser degree the alkaline earths, calcium and magnesium.

To investigate the effect of alkali ions on the sand surface, an experiment was carried out in which Sand F was soaked in 10% aqueous sodium hydroxide in order to partially convert the surface character from purely silica-like with --SiOSi-- and --SiOH groups to one with --SiONa groups. After each week of contact with the alkali solution a sample of the sand was withdrawn, washed and dried and set aside for subsequent testing. This procedure was continued for four weeks, thereby collecting four samples of alkali-treated sand. At the end of the four-week treatment, a final portion of the sand was washed free of alkali, dried and then subjected to the standard acid treatment with 10% sulfuric acid. All five of these sand samples along with a sample of untreated sand were then tested at the same time using silane-modified cold box binder.

As shown in Fig. 15, changes in sand performance due to alkali treatment occur slowly but begin to become quite evident after a two-to three week treatment. A steady decrease in core strength performance is observed at each level of test humidity as the alkali treatment is extended from one to four weeks. The effect of acid treatment of the final alkali-modified sand dramatically demonstrates a reversal of the deleterious effects due to alkali treatment.

If during the alkali treatment it can be assumed that --SiOSi-- and --SiOH are converted to --SiONa surface sites, then subsequent acid treatment reforms --SiOSi-- and --SiOH . These latter surface sites thus must be capable of strong, water resistant interactions with silane molecules via hydrogen bonding or chemical reaction whereas the --SiONa surface sites provide weak, or water-sensitive interactions. Schematically, the situation can be described as follows:

Presumably similar weak interaction effects could result from the presence of --SiOK and possibly --SiOMg or --SiOCa surface sites.

Conclusions

Acid treatment of foundry sands is an effective method for improving strength characteristics of cores and molds bonded with resinous organic binders. Although current commercial foundry binders provide some performance benefits with the modified sands, much greater improvements result from use of binders modified with silane adhesion promoters.

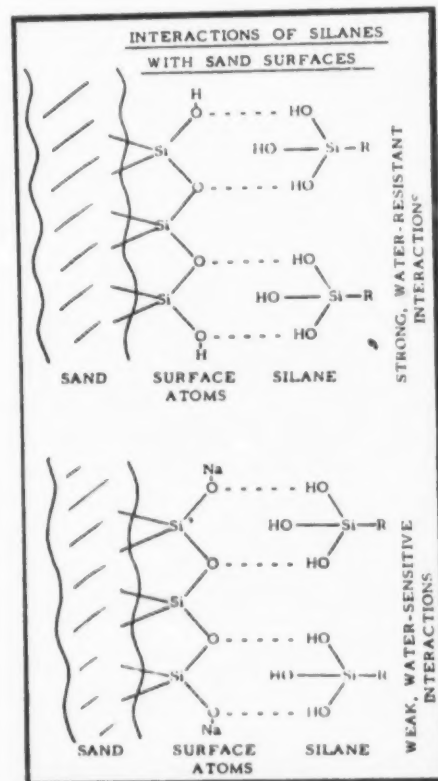
The acid-modifying process is shown to be effective with a representative sampling of foundry sands and is expected to have widespread utility with regard to sand type and source. Binders which have been modified to provide improved core strength performance using acid-treated sands are the urethane cold box, urethane nobake, alkyd-iso-yanate nobake, furan nobake, zero-nitrogen furan nobake and the furan hot box system.

While any method of contacting sand with aqueous acid appears satisfactory, the chemical changes occurring at the sand surface are rate processes and are dependent on contact time, temperature and acid concentration. Excess acid must be washed from the sand which then can be dried in normal operations.

Study of the chemical and physical changes at the sand surface resulting from acid treatment suggests that chemical factors are dominant in controlling effectiveness of the silane adhesion promoters. Alkali treatment of high purity Sand F promotes silane ineffectiveness and acid treatment reverses this phenomenon. Thus it is concluded that silanes interact strongly with pure silica surfaces but only weakly with surfaces containing alkali and possibly alkaline earth ions.

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Evaluation of the Surajdewal Sand for the Glass Industry

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The raw sand available at Surajdewal was examined chemically and petrographically and some beneficiation work was carried out to investigate the suitability of the sand for the glass industry. The sand, as such, corresponds to Grade 3 of IS: 488-1963. During beneficiation it was observed that washing with water lowered the iron content, bringing the sand almost equivalent to Grade 2, and on leaching with 1% H_2SO_4 the sand was found to be in conformity with Grade 1. The coarseness of the sand was reduced through grinding and this led to significant improvement in particle size distribution, as preferred by the glass industry. Trial melting was carried out with untreated and different grades of treated sands. The results were found to be encouraging for utilization in the glass industry.

Introduction

The glass industry in Gujarat is on the brink of a major expansion. At Surajdewal (Dist. Surendranagar) huge deposits of sand are available and these are being used, to some extent, by the glass industry at present. Evaluation of this sand was taken up at the instance of Gujarat Mineral Development Corporation (GMDC), Ahmedabad.

The basic objective of this work was to understand how, through beneficiation, the sand could be made useful for the glass industry, e.g. sheet glass, container glass, where the requirements are in bulk. In sheet or container glass units, a sand whose alumina content remains constant, and Fe_2O_3 and fineness are within tolerable limits, is preferred. The beneficiation process, if any, should also be simple and cost effective.

Several workers¹⁻¹⁰ have earlier adopted different methods for removing the harmful impurities like Fe_2O_3 and heavy minerals like zircon, rutile etc from sands. These different methods are: washing, sieving and chemical methods using different reagents such as hydrochloric acid, combination of sulphuric acid and sodium carbonate, oxalic acid etc. Flotation, magnetic separation and/or a combination of both have also been used. The beneficiation methods followed in this work are washing, grinding and acid leaching.

Two samples from different sources of Surajdewal were briefly evaluated earlier by Nayak and Prasad.¹¹ For the present investigation the samples were collected from a third source of the same region.

Occurrence and Geology of the Sand

The sand sample, received from Gujarat Mineral Development Corporation, was from their mines in Waori village, situated in Chotila Taluka of Surendranagar district. The mining area is about 31 hectares and lies 10 km north-east of Chotila, which is about 170 km from Ahmedabad and situated on Ahmedabad-Kandla National Highway. The mining area is approachable both by rail and road.

The area mainly constitutes a flat level ground, comprising sandstone of Surajdewal formation belonging to lower cretaceous Dharnghdhar series¹² which are part of the Jura-cretaceous formations of Gujarat. The total thickness of sandstones may be as much as 60 to 70 metres but the quarries are only 3 to 4 metre deep. The

Directorate of Geology and Mining have drilled about 14 bore holes of different depths, up to 12 metres, in this area. The inferred reserves are more than 100 million tonnes.

The sandstone consists of sub-rounded to angular grains of quartz, cemented together generally by siliceous matter and occasionally by ferruginous and clayey matter. The grain size varies from coarse to fine. The sandstone is mostly white in colour, stained partially with yellowish reddish colour due to iron oxide.

Chemical analyses of the samples from the pits, as well as core samples from bore holes, reveal a wide variation in silica content, ranging from 85 to 98%. Iron and/or alumina form the chief impurities which vary from less than 0.02 to as much as 10%.

Experimental

The samples, as received from GMDC, were examined visually and under a petrological microscope.

Chemical analyses were carried out on the samples as received, as well as on the fraction lying between 600 and 125 microns.

The sand sample was stirred with water for 10 minutes and allowed to settle. Then the water was decanted off. The process was repeated for 10 times and the sample was dried at 110°C.

The sample was leached with 1% H_2SO_4 solution for 8 hrs and washed with water till the supernatant liquid became neutral. It was then dried at 110°C.

A window glass composition of SiO_2 -72.00, Al_2O_3 -1.5, CaO 9.0, MgO -3.0 and Na_2O -14.5 was taken as the basis of comparison. Four glass batches containing raw sand, water washed sand, acid leached sand and ground sand, designated as no. 1, 2, 3 & 4 respectively were melted around 1450-1500°C. The molten glasses were visually examined for colour.

Results and Discussion

Results of sieve analysis are given in Table I.

Table I: Mechanical analysis of Surajdewal sand (as received)

Mesh size (BS)	% residue
+ 18 (1.00 mm)	nil
+ 25 (600 micron)	nil
+ 36 (420 micron)	47.57
+ 52 (300 micron)	28.03
+ 72 (210 micron)	13.88
+ 100 (150 micron)	5.54
+ 120 (125 micron)	3.03
- 120	1.7
	99.75

From the results of chemical analyses, shown in Table II, it may be observed that the sand, as received, corresponds to Grade 3 of IS: 488-1963¹³ and by washing with water and on leaching with 1% H_2SO_4 it can be upgraded to Grade 1.

Table II: Chemical analysis of Surajdewal sand

Constituents	Raw sand	Raw sand (-600 micron +125 micron)	Washed with water (10 mins - 10 times)	Washed with 1% H ₂ SO ₄ soln for 8 hrs	Ground for 15 mins
SiO ₂	98.00	98.10	98.40	98.83	98.25
Fe ₂ O ₃	0.10	0.10	0.075	0.04	0.05
TiO ₂	trace	trace	trace	trace	trace
Al ₂ O ₃	0.93	0.90	0.70	0.39	0.90
CaO	0.40	0.40	0.40	0.33	0.40
MgO	trace	trace	trace	trace	trace
Na ₂ O	0.05	0.05	0.05	0.05	0.05
K ₂ O	0.02	0.02	0.02	0.02	0.02
LOI	0.58	0.49	0.42	0.39	0.36

Table III: Effect of grinding on particle size distribution

Mesh	% residue					Sand: (kg)	Porcelain balls: (kg)	Water: (lit)	Time (hr)			
	Sand: (kg)	Alumina balls: (kg)	Water: (lit)	Time (hr)	Sand: (kg)					Porcelain balls: (kg)	Water: (lit)	Time (hr)
	1:4:2:8		2:8:2.5:4		1:4:1:0.25		2:3:1.5:0.25		1:2:1:0.25			
16 (100 mm)	—		—		—		—		—			
25 (600 micron)	—		—		—		—		—			
36 (420 micron)	0.050		0.082		2.195		15.145		16.190			
52 (300 micron)	0.212		0.163		11.210		35.370		33.105			
72 (210 micron)	0.180		0.090		27.630		21.608		22.107			
100 (150 micron)	0.805		0.392		19.065		10.190		10.099			
150 (106 micron)	—		0.689		13.647		7.57		6.484			
—150	98.646		97.967		26.183		8.90		11.210			
	99.893		99.283		99.93		99.08		99.195			

The size grading, as indicated in IS specification, does not cover the particle size distribution of the sand between 600 and 125 micron. The glass industry on the contrary prefers a medium grained sand. In this respect, the BS specification adequately covers the particle size distribution as the industry would prefer.

By comparing with the BS specification¹⁴ on sand for colourless glasses, it had been found that the sand was coarse. To reduce the particle size, the method of grinding was adopted and after several attempts it was found that a charge of 2 kg of sand and 3 kg of alumina balls with 1.5 litre of water, on being ground for 15 mins, gave a sample (up to 67%) nearer to that of the British specification. The results after grinding are shown in Table III.

Trial melts, with untreated and different grades of treated sands gave encouraging results. The results of visual examination for molten glasses are shown in Table IV.

It was observed that through washing some amount of iron could be removed, and the effect was remarkable with 1% H₂SO₄ solution. It was also noticed that the colour of the sand sample under investigation changed from off-white to white. Grinding of the sand served a dual purpose. Through grinding operation, the particle size distribution was brought within the tolerable limits, as was preferred in the industry. The iron content was also reduced, making the sand equivalent to Grade 2, which was suitable for the sheet or container glass industry.

Table IV: Colour of glass from Surajdewal sand

Melt	Particulars of sand used	Colour of glass
1	Raw sand	Greenish yellow
2	Water washed sand	Bluish green (darker than 1)
3	1% H ₂ SO ₄ leached sand	Pale green (lighter than 1)
4	Ground sand	Yellowish green (darker than 3, but lighter than 2)

Conclusions

The raw sand of Surajdewal, belongs to Grade 3 of IS: 488-1963. Through grinding, the sand can be upgraded to Grade 2, suitable for producing decolourised bottle ware, where a slight tint is permissible. By simple beneficiation this can be improved to Grade 1 and used in the manufacture of colourless container ware.

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RECOVERING BYPRODUCT HEAVY MINERALS FROM SAND AND GRAVEL, PLACER GOLD, AND INDUSTRIAL MINERAL OPERATIONS

by

J. M. Gomes,¹ G. M. Martinez,² and M. M. Wong

ABSTRACT

The Bureau of Mines, as part of an effort to maximize minerals and metals recovery from domestic resources, has investigated the feasibility of recovering heavy minerals as byproducts from sand and gravel, placer gold, and industrial mineral operations in northern California. Sand samples from about 50 locations were treated by gravity separation to yield heavy-mineral concentrates (black sands). Mineral compositions of the concentrates were determined by chemical analysis and mineralogical examination. Individual zircon, ilmenite, magnetite, platinum-group metals, thorium, and silica products were prepared from heavy-mineral concentrates by selective separation using low- and high-intensity magnetic, high-tension, and flotation equipment.

INTRODUCTION

As part of its goal to maintain an adequate supply of minerals to meet national economic and strategic needs, the Bureau of Mines investigated the recovery of byproduct heavy minerals (HM) from sand and gravel, placer gold, and industrial mineral operations in northern California. The recovery of gold from sand and gravel operations has been practiced for decades, but the recovery of other minerals has been neglected. The recovery of heavy minerals would have no additional environmental impact because they would be obtained as byproducts.

The heavy-mineral concentrates, referred to as "black sands," have intrigued miners since the first placer gold was recovered. The mineral composition of California black sands was investigated by Day and Richards of the U.S. Geological Survey in 1905 (4),⁴ and a mineral utilization study was made by Day, Wilson, and Clevenger (5). Heavy minerals found in California black sands include magnetite, ilmenite, hematite, chromite, zircon, garnet, scheelite, cinnabar, gold, and platinum-group metals (PGM). All of these minerals

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⁴Underlined numbers in parentheses refer to items in the list of references at the end of this report.

have economic potential. The increase in value based on 1958 dollars for several of these minerals during the period 1958-76 is shown in table 1. The values of rutile and scheelite have increased twofold to threefold during the 18-year period, the values of magnetite and chromite have increased 1.5-fold, and the value of zircon has increased over sevenfold. While the value of ilmenite remained constant, the value of gold and platinum has doubled.

TABLE 1. - Approximate value increase of heavy minerals

	1958	1976
Magnetite.....cent per pound..	0.5	0.75
Chromite.....cents per pound..	2	3
Ilmenite.....do.....	1.5	1.5
Rutile.....do.....	5	14
Zircon.....do.....	2	15
Scheelite.....do.....	90	250
Gold.....dollars..	520	1,000
Platinum.....do.....	550	1,150

^a Based on common 1958 dollars calculated from inflation rate 1958 to 1976, U.S. Bureau of Mines.

Source: Mineral Facts and Problems, BuMines Bull. 585, 1960; Metals week, Vol 47, No. 51, Dec. 20, 1976.

Only a few successful attempts have been reported in the literature on recovering heavy minerals as byproducts from sand and gravel operations. Iron ore was recovered in England (1). The Bureau of Mines reported the recovery of ilmenite, zircon, kyanite, and rutile in the Southeastern United States (2-3). Free gold has been recovered from sand and gravel operations in California for over 40 years. In the late 1930's, over \$200,000 in gold was recovered from the aggregates used in building Friant Dam on the San Joaquin River (6). In recent years, about one-third of California's gold production was derived from sand and gravel operations. Several of the plants that recover gold are located on streams flowing through the Mother Lode or other gold-bearing areas.

The objective of this investigation was to determine the feasibility of recovering heavy-mineral concentrates from sand and gravel, placer gold, and industrial mineral operations and of preparing individual mineral products from these concentrates by various beneficiation techniques. Sand samples were obtained from various northern California locations, and heavy-mineral concentrates were prepared from them. Chemical analyses and mineralogical examinations of the heavy-mineral concentrates were made to identify and determine the quantities of the individual minerals. Recovery of large quantities of heavy-mineral concentrates by gravity concentration was performed on the samples that showed significant quantities of heavy minerals. Separation of the bulk heavy-mineral concentrates into individual mineral concentrates then was investigated using magnetic, high-tension, and flotation equipment.

HEAVY-MINERAL SAMPLING

The locations of northern California operations that provided samples for this investigation are shown in figure 1. The sand and gravel and placer gold operations are principally located in Quaternary alluvial deposits in stream channels or flood plains. These deposits are mainly derived from the weathering of mineralized areas in the Sierra Nevada Range, Coast Range, and Klamath Mountains. Sand and gravel operators in northern California process about 20 million tons of material annually. The placer gold deposits are worked intermittently employing washing plants with ore capacities of 20 to 500 tons/hr.

The sampling procedure used in this study began by obtaining a 40- to 50-lb sample of washed cement or mortar sand from each of the sand and gravel operations. Almost all the recoverable heavy minerals occur in these sand fractions. Data used to calculate the percentage of sand in the deposit were obtained so that the heavy-mineral content of the in-place material could be calculated. Heavy-mineral concentrates were obtained also from placer gold



FIGURE 1. - Northern California sample locations.

operations. The operators provided data on ratio of concentration so that calculations could be made to determine the approximate heavy-mineral content of the in-place deposit.

Heavy-mineral concentrates were prepared from sand samples using a Humphreys spiral concentrator. The concentrates were analyzed for Cr_2O_3 , Fe_2O_3 , TiO_2 , ZrO_2 , gold, silver, and platinum-group metals, and a mineralogical examination was made. The concentrations of chromite, ilmenite, and zircon in the deposit were calculated from the analysis. The magnetite concentration was determined by low-intensity magnetic separation and chemical analysis, and an electron microprobe analysis was made on some samples to determine the mineral association and trace elements. The total heavy minerals was determined by a heavy-medium separation procedure using diiodomethane (CH_2I_2) with a specific gravity of 3.3. Samples showing less than 0.2 wt-pct heavy minerals in the deposits were not reported in the tables, but their locations are shown in figure 1.

Results of samples from the Pit, Feather, and Yuba Rivers are shown in table 2. Total heavy-mineral content in the deposits ranged from 0.3 to 2.0 wt-pct. Heavy minerals present were generally magnetite, up to 25 lb/ton, and ilmenite, up to 10 lb/ton. The chromite content was usually about 1 lb/ton, but the French Corral sample contained 3 lb/ton. The Cherokee and Shady Creek samples contained 8 lb/ton zircon, the only samples having a significant zircon content. All samples contained gold, ranging from <0.0001 to about 0.02 oz/ton.

The composition of samples obtained from the Klamath Mountains and Coast Range areas are shown in table 3. The samples showed 0.2 to 2.0 wt-pct heavy minerals in the deposits. Major minerals present were magnetite (up to 22 lb/ton), and ilmenite, (up to 5 lb/ton). The Elliot Creek and Russian River (Windsor) samples contained 5 lb/ton chromite; most other samples contained <1 lb/ton. The zircon content in all samples from this area was 1 lb/ton or less. The Elliot Creek sample also contained 0.03 lb/ton scheelite. This is a significant finding since there are no reported tungsten occurrences in the Siskiyou Mountains. Gold contained in the deposits ranged from <0.0001 to 0.02 oz/ton and platinum-group metals ranged from <0.0001 to 0.0004 oz/ton. Samples from Healdsburg and Cloverdale on the Russian River contained 0.0007 and 0.0005 oz/ton gold, respectively. This is significant since the Russian River area is not considered a gold-bearing area.

TABLE 2. - Samples from Pit, Feather, and Yuba Rivers area¹

Map No. ²	Location	Total IM, wt-pct	Minerals, lb/ton				Oz/ton		
			Magnetite	Ilmenite	Chromite	Zircon	Others ³	Gold	PGM
1	Sand and gravel:	0.7	2	5	<1	<1	6	<0.0001	<0.0001
2	Pit River (Alturas).....	.3	3	<1	<1	<1	2	.0001	<.0001
3	Long Valley.....	1.5	7	1	<1	1	21	.0001	<.0001
4	Butte Creek.....	.7	<1	4	1	8	3	.003	<.0001
5	Cherokee tailing dump...	1.0	8	3	<1	1	8	.0002	<.0001
6	Feather River (near Oroville).	1.2	12	1	<1	1	10	.0005	.0010
7	Spanish Creek (Quincy).. Yuba River (Marysville).	.5	6	1	<1	<1	2	.0001	<.0001
8	Placer mines:								
9	Yuba Goldfields.....	1.0	6	1	1	1	11	.002	.0001
10	French Corral.....	1.4	1	8	3	1	15	.010	<.0001
11	Shady Creek.....	2.0	19	10	<1	8	3	.020	.0001
12	Emory Isle.....	1.8	25	1	1	1	8	.028	.001
12	Jameson Creek ⁴	1.6	19	5	<1	<1	7	.03	<.0001

¹Values based on in-place deposit.²Locations in figure 1.³Minerals such as garnet, sphene, pyroxenes, olivine, etc.⁴Also contained 0.03 lb/ton scheelite.

TABLE 3. - Samples from the Klamath Mountains and Coast Range area¹

Map No. ²	Location	Total IM, wt-pct	Minerals, lb/ton					Oz/ton	
			Magnetite	Ilmenite	Chromite	Zircon	Others	Gold	PCM
13	Sand and gravel:	0.6	6	<1	1	1	4	0.0002	0.0001
14	Smith River.....	.8	4	1	<1	<1	10	.0006	<.0001
15	Scotts River (Ft. Jones). Reading Creek (Douglas City).	1.4	5	5	1	<1	17	.003	.0001
16	Sacramento River (Redding).	1.0	5	1	.1	.1	13	.0003	.0001
17	Clear Creek (Redding)....	.2	3	1	.1	<1	0	.003	.0001
18	Blue Tent Creek (Red Bluff).	.7	9	1	<1	1	3	.0001	.0001
19	Garces River (Gualala)...	.3	1	<1	.1	<1	5	.0001	.0001
20	Putah Creek (Middletown).	.6	2	.1	3	.1	6	.0001	.0001
21	Russian River (Cloverdale).	.4	2	<1	.1	1	5	.0005	.0001
22	Russian River (Healdsburg).	.4	2	1	.1	1	4	.0007	<.0001
23	Russian River (Windsor)..	.4	1	1	5	1	1	.0001	<.0001
24	Cache Creek (Madison)....	.2	1	<1	<1	1	1	.0001	.0001
25	Dillon Beach.....	.2	1	.1	1	1	2	.0005	.0002
26	Placer mines: Elliot Creek ⁴ (Siskiyou Co.).	2.0	22	1	5	1	12	.02	.0004

Values based on in-place deposit.

¹Values based on in-place deposit.²Locations in figure 1.³Minerals such as garnet, sphene, pyroxenes, and olivine.⁴Also contained 0.03 lb/ton scheelite.

Results of samples from the Sacramento-Tahoe area are shown in table 4. Samples from the sand and gravel operations showed from <1 to 33 lb/ton magnetite in the deposits and up to 7 lb/ton ilmenite. Zircon contents ranged up to 3 lb/ton and chromite, <1 lb/ton. The sample from the waste ponds of a silica-clay operation at Ione contained 400 lb/ton altered ilmenite and 83 lb/ton zircon. This sample was unique in that the relatively low-specific-gravity minerals, such as quartz and clay, had been removed by the operator, resulting in tailings containing 27 wt-pct heavy minerals. This material is a potential source for both titanium minerals and zircon. All samples showed gold in the deposits ranging from 0.0001 to 0.002 oz/ton. The American River and Ione samples also showed about 0.001 oz/ton platinum-group metals; other samples, <0.0001 oz/ton.

TABLE 4. - Samples from Sacramento-Tahoe area¹

Map No. ²	Location	Total HM, wt-pct	Minerals, lb/ton					Oz/ton	
			Magnetite	Ilmenite	Chromite	Zircon	Others	Gold	PGM
27	Sand and gravel: Bear River (Colfax).	0.8	4	7	<1	3	1	0.002	<0.0001
28	Bear River (Meadow Vista).	.4	1	2	<1	<1	4	.0001	<.0001
29	Greenhorn Creek..	.6	<1	2	<1	<1	9	.0005	<.0001
30	Martis Creek.....	.6	3	1	<1	<1	2	.0001	<.0001
31	Kleinsorge.....	1.4	15	3	<1	<1	7	.001	<.0001
32	American River (Teichert).	.7	10	1	<1	<1	2	.001	.0010
33	American River (Granite).	1.0	10	1	<1	<1	8	.001	.0010
34	Consummes River (Elk Grove).	.8	1	3	<1	<1	12	.0001	<.0001
35	Mokelumne River..	2.6	33	7	<1	<1	9	.0007	.0001
36	Silica-clay: Ione ³	27.0	1	400	<1	83	57	.002	.0015

¹Values based on in-place deposit.

²Locations in figure 1.

³Minerals such as garnet, sphene, pyroxenes, kyanite, tourmaline, and olivine.

⁴Values based on waste material.

BENEFICIATION

Gravity Concentration

Five materials were selected for beneficiation studies: washed sand samples from the American River, Mokelumne River, Cherokee tailings, the heavy-mineral tailings from the silica-clay operation at Ione, and the jig concentrate (black sand) from the Yuba Goldfields dredge. The first three washed sand samples and the Ione heavy-mineral tailings were treated on a Humphreys spiral to recover concentrates containing 58 to 90 wt-pct heavy minerals. The procedure adopted was to recover a primary concentrate weighing 20 to 50 lb from 400 to 500 lb of feed material. The primary heavy-mineral concentrate then was upgraded to recover a cleaner concentrate. The results from preparing the heavy-mineral cleaner concentrates are shown in table 5. The recovery of heavy minerals from each of the three sand samples was approximately 90 pct. The recovery of heavy minerals in the cleaner concentrate from the Ione tailings was 72 pct. An additional 16 pct of the heavy minerals was in a scavenger concentrate prepared from the primary tailings. The scavenger concentrate and the cleaner tailings contained 24 pct of the heavy minerals; these products would have to be recycled.

TABLE 5. - Recovery of heavy minerals from bulk sand samples

Source	IEI, wt-pct			Recovery of IEI, pct	
	Leads	Primary conc.	Cleaner conc.	Primary conc.	Cleaner conc.
American River (Teichert).....	1.4	22.4	90	93	90
Cherokee.....	.6	10.8	58	99	91
Ione.....	27	55.4	81	80	72
Mokelumne River.....	2.6	38.0	70	90	86

The analyses of the four cleaner concentrates and the jig concentrate from the Yuba Goldfields dredge are shown in table 6. The significant minerals present were magnetite, ilmenite, zircon, gold, and platinum-group metals. Techniques for fractionating the concentrates are discussed individually in the following sections.

TABLE 6. - Analyses of heavy-mineral cleaner concentrates

Source	Pct				Oz/ton	
	Cr ₂ O ₃	Fe ₂ O ₃	TiO ₂	ZrSiO ₄	Au	Pt
American River (Teichert).....	0.3	79.8	3.2	0.8	0.06	1.0
Cherokee.....	1.2	13.8	8.4	16.0	.17	.001
Ione.....	.2	18.3	41.0	16.4	.005	.001
Mokelumne River.....	.2	67.6	3.2	.3	.02	(^a)
Yuba Goldfields ^b	2.5	71.0	11.5	.5	.08	.004

^a Most of the gold had been removed by operators beforehand.

^b Not detected.

^c Jig concentrate.

Fractionation of Heavy-Mineral Concentrates

American River

A concentrate containing 90 wt-pct heavy minerals was prepared from the sand sample obtained from the Teichert operation at Sacramento. The sample had been treated previously for gold recovery by the operator, accounting for the gold content of 0.06 oz/ton, which was lower than the platinum-group-metal content of 0.4 oz/ton. Preliminary study of the American River concentrate indicated that magnetite, platinum-group metals, and thorium values were significant. The processing sequence for preparing and fractionating the concentrate is shown in figure 2.

The heavy-mineral concentrate was fractionated by low-intensity magnetic separation to yield a magnetite product containing 75 pct of the feed material. Analysis of the magnetite product showed, in weight-percent: Fe₂O₃, 96; Cr₂O₃, 0.3; TiO₂, 2.0; ZrSiO₄, <0.1; and platinum-group metals, 0.014 oz/ton. The nonmagnetic fraction contained the following platinum-group metals, in ounces per ton: Pt, 1.5; Pd, 0.23; Ir, 0.84; Os, 0.82; Rh, 0.26; and Ru, 0.11.

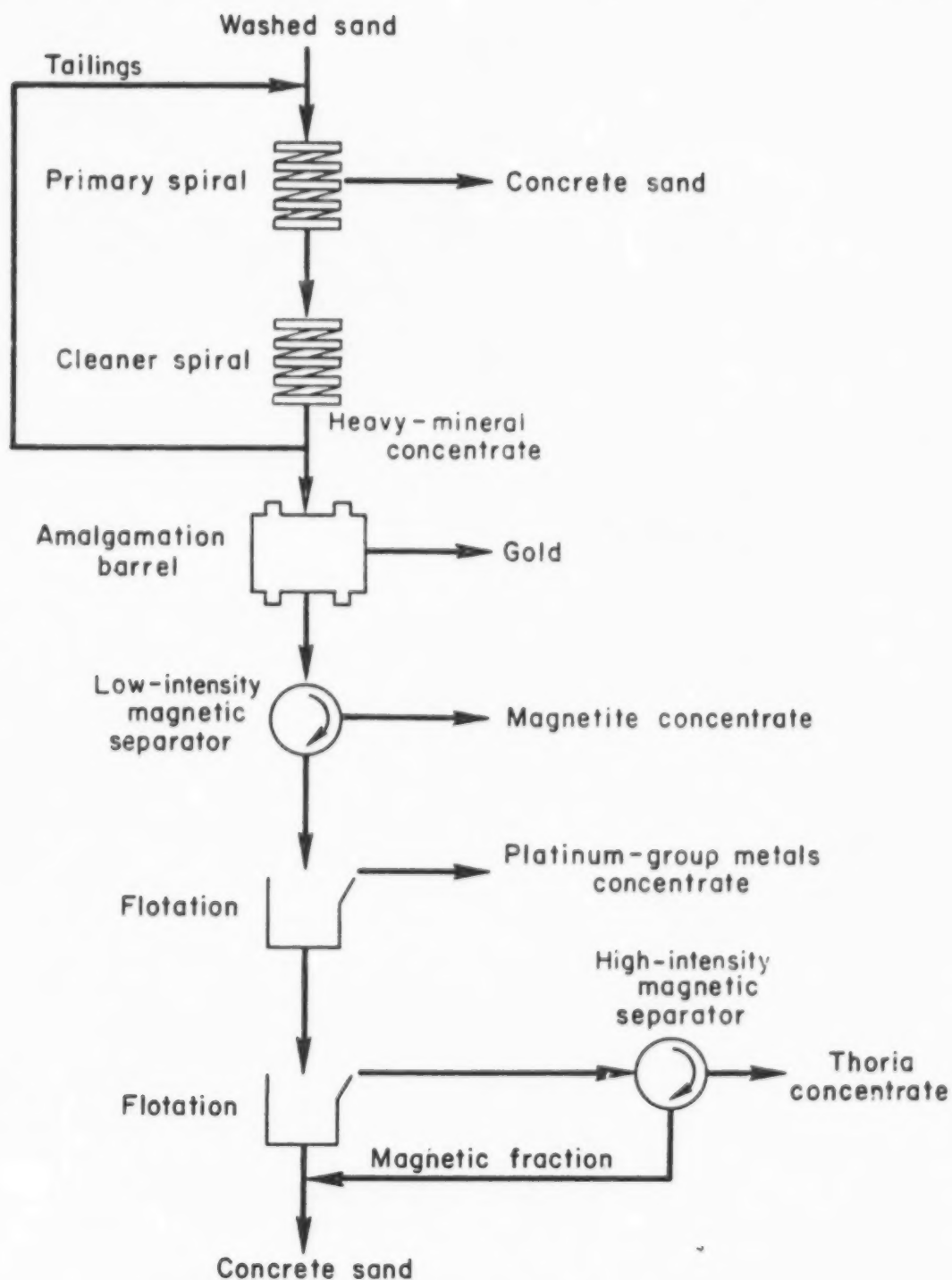


FIGURE 2. - Sequence for processing American River sand.

Microprobe analysis identified ferroplatinum and osmium-iridium alloys. Platinum-group-metal concentrates were prepared from the nonmagnetic fraction by flotation using potassium amyl xanthate and Dowfroth 250. Over 90 pct of the platinum-group metals was recovered from the low-intensity nonmagnetic fraction. The analyses and distribution of the major platinum-group metals are shown in table 7.

TABLE 7. - Analysis and distribution of platinum-group metals in heavy-mineral concentrate from American River

Sample	Wt-pct	Analysis, oz/ton			Distribution, pct		
		Pt	Ir	Os	Pt	Ir	Os
Low-intensity nonmagnetic..	100	1.50	0.84	0.82	100	100	100
Flotation concentrate.....	.4	348.00	190.00	188.0	93	91	92
Flotation tailings.....	99.6	.11	.08	.07	7	9	8

The flotation tailings, containing 0.68 wt-pct ThO_2 and 0.03 wt-pct U_3O_8 , were treated by fatty-acid flotation to recover a radioactive concentrate containing 3.3 wt-pct ThO_2 and 0.15 wt-pct U_3O_8 . The radioactive minerals in the flotation concentrate were upgraded by high-intensity magnetic separation to remove weakly magnetic minerals such as ilmenite and garnet. The analysis and distribution of the thorium and uranium oxide constituents are shown in table 8. The thorium was present as thorite (ThSiO_4). No specific uranium minerals could be identified by electron microprobe examination.

TABLE 8. - Analysis and distribution of radioactive oxides in heavy-mineral concentrate from American River

Sample	Wt-pct	Analysis, wt-pct		Distribution, pct	
		ThO_2	U_3O_8	ThO_2	U_3O_8
Pt flotation tailings.....	100	0.68	0.03	100	100
Flotation tailings.....	86	.25	.01	32	33
Flotation concentrate.....	14	3.3	.15	68	67
Flotation concentrate:					
High-intensity nonmagnetic...	4.5	8.90	.40	59	60
High-intensity magnetic.....	9.5	.65	.02	9	7

Mokelumne River

The analysis of the heavy-mineral concentrate prepared from the Mokelumne River sample indicated that gold and magnetite were the only significant values that warranted recovery. The processing sequence for recovering gold and magnetite from the Mokelumne River washed sand is similar to the sequence devised for the American River sand sample shown in figure 2. The platinum-group metals and radioactive minerals in the Mokelumne River sand sample were insignificant and, therefore, no attempt was made to recover them.

⁵Reference to specific brands is made for identification only and does not imply endorsement by the Bureau of Mines.

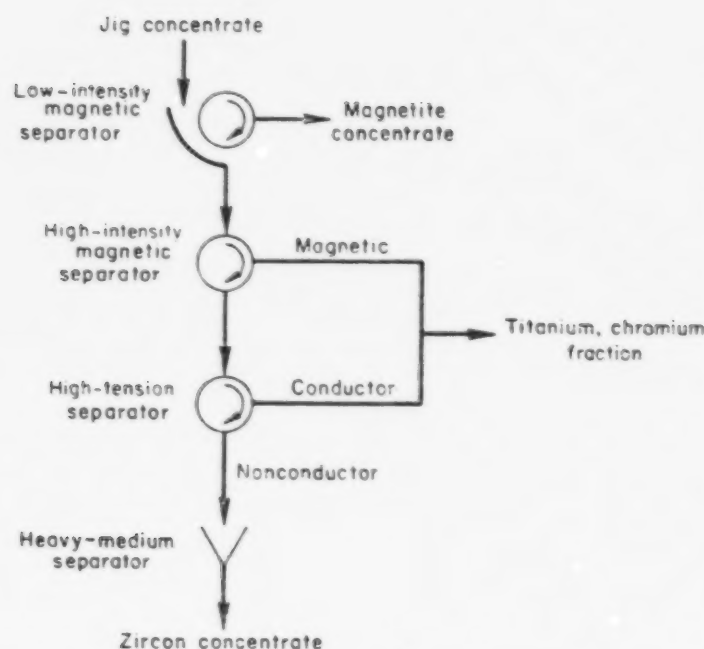


FIGURE 3. - Sequence for processing Cherokee tailings.

The recovery of gold was approximately 100 pct. Eighty-two percent of the iron was recovered in a magnetite product containing 51 pct of the heavy-mineral concentrate. This magnetite product was extremely high grade with the following analysis, in weight-percent: Fe_2O_3 , 96; TiO_2 , 0.7; Cr_2O_3 , 1.7; and SiO_2 , 1.9. Attempts to recover an ilmenite product were not successful as the magnetic fraction produced by high-intensity magnetic separation contained only 14 wt-pct TiO_2 .

Cherokee Tailings

The Cherokee tailings are the downstream waste material from the old hydraulic mining operation at Cherokee, Lutte County. The

Baldwin Construction Co. presently operates a sand and gravel pit on the tailings. Analysis and preliminary study of the concentrate indicated that gold, zircon, and a high-grade silica product could be recovered. The processing sequence for preparing a cleaner concentrate, amalgamating the concentrate for gold recovery, and treating the concentrate with high-intensity magnetic and heavy-medium separations to recover a zircon product is shown in figure 3. Zircon recovery in the product was 98 pct; the results are shown in table 9.

TABLE 9. - Fractionation of Cherokee cleaner concentrate

Sample	Wt-pct	Analysis, wt-pct			Distribution, pct		
		Fe_2O_3	TiO_2	ZrSiO_4	Fe_2O_3	TiO_2	ZrSiO_4
Cleaner conc.....	100	13.6	8.5	17.0	100	100	100
High-intensity separation:							
Magnetic.....	29	44.0	26.0	.2	94	88	<1
Nonmagnetic.....	71	1.1	1.4	24.0	6	12	100
Heavy-medium:							
Sink.....	18	2.1	3.0	93.0	3	6	98
Float.....	53	.8	1.0	.5	3	6	2

Tailings from the primary spiral concentrator, containing about 96 wt-pct SiO_2 , were treated with high-intensity magnetic and high-tension separations to recover about 85 pct of the silica in a product with the following analysis, in weight-percent: SiO_2 , 99; Al, 0.1; Ca, 0.02; Fe, 0.07; Mg, 0.001; Ti, 0.1; and Zr, 0.1.

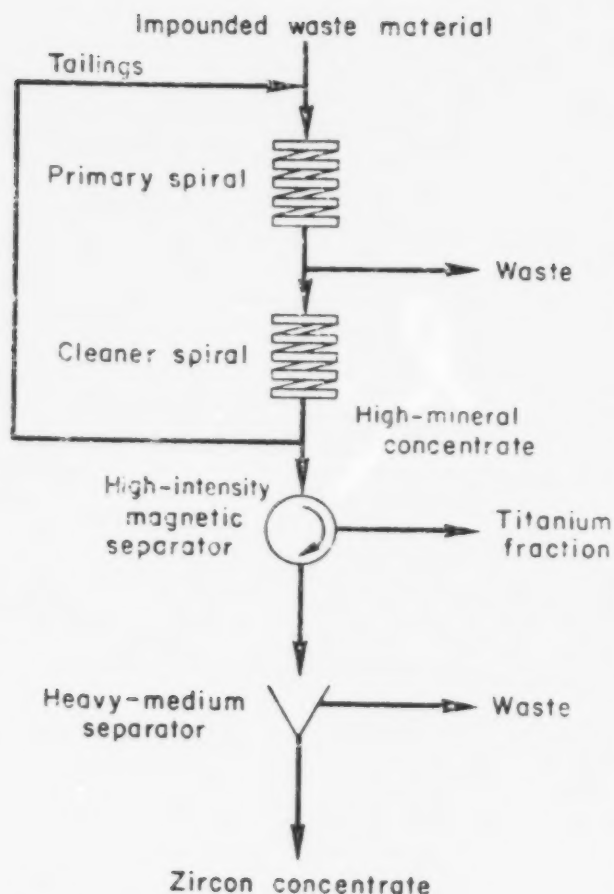


FIGURE 4. - Sequence for processing lone waste material.

used as a feed material for the preparation of titania pigment by the chloride process. About 95 wt-pct of the material is in the minus 65 plus 200-mesh size range, which is a suitable particle size for a fluid-bed reactor.

Lone Waste Material

The processing sequence used to upgrade and fractionate the waste material from the silica-clay operations at Lone, Anderson County, is shown in figure 4. The cleaner concentrate containing 81 wt-pct heavy minerals was fractionated by high-intensity magnetic separation to yield a magnetic fraction containing 96 pct of the TiO_2 and a nonmagnetic fraction containing 97 pct of the zircon. The nonmagnetic fraction was treated by heavy-medium separation to yield a product assaying 89.6 wt-pct $ZrSiO_4$. Over 95 pct of the zircon in the nonmagnetic fraction was recovered in this product. The results are shown in table 10.

The ilmenite or titanium mineral fraction contained 63.5 wt-pct TiO_2 and 26.3 wt-pct Fe_2O_3 ratio of 2.4:1.0. Most commercial alluvial ilmenite has a $TiO_2:Fe_2O_3$ ratio of about 2.0:1.0. The major species identified by X-ray diffraction were a noncrystalline mineral and pseudorutile ($Fe_2O_3 \cdot 3TiO_2$). The product probably would be classified as leucoxene, a mixture of highly altered titanium minerals. This material could possibly be

TABLE 10. - Fractionation of Lone concentrates

Sample	Wt-pct	Analysis, wt-pct			Distribution, pct		
		Fe_2O_3	TiO_2	$ZrSiO_4$	Fe_2O_3	TiO_2	$ZrSiO_4$
Cleaner conc.....	100	17.7	42.3	16.9	100	100	100
High-intensity magnetic separation:							
Magnetic.....	64	26.3	63.5	.6	95	96	3
Nonmagnetic.....	36	2.5	4.5	46.0	5	4	97
Heavy-medium:							
Sink.....	18	1.1	8.8	89.6	1	4	95
Float.....	18	3.9	.2	2.5	4	<1	2

Yuba Goldfields Black Sand

A jig concentrate containing 95 wt-pct heavy minerals was obtained from the Yuba Goldfields dredge at Hammonton, Calif. The concentrate was previously treated in amalgamation barrels for gold recovery. The material contained the following, in weight-percent: Cr_2O_3 , 2.5; Fe_2O_3 , 71; TiO_2 , 11.5; and ZrSiO_4 , 0.5. It also contained 0.08 oz/ton gold and 0.04 oz/ton platinum-group metals. The Yuba Goldfields concentrate was examined by electron microprobe to determine the mineralogical associations. The probe indicated a complex association between magnetite and titanium. Individual grains of magnetite contained from 0.2 to 16 wt-pct TiO_2 . Titanium in the major species was as follows, in

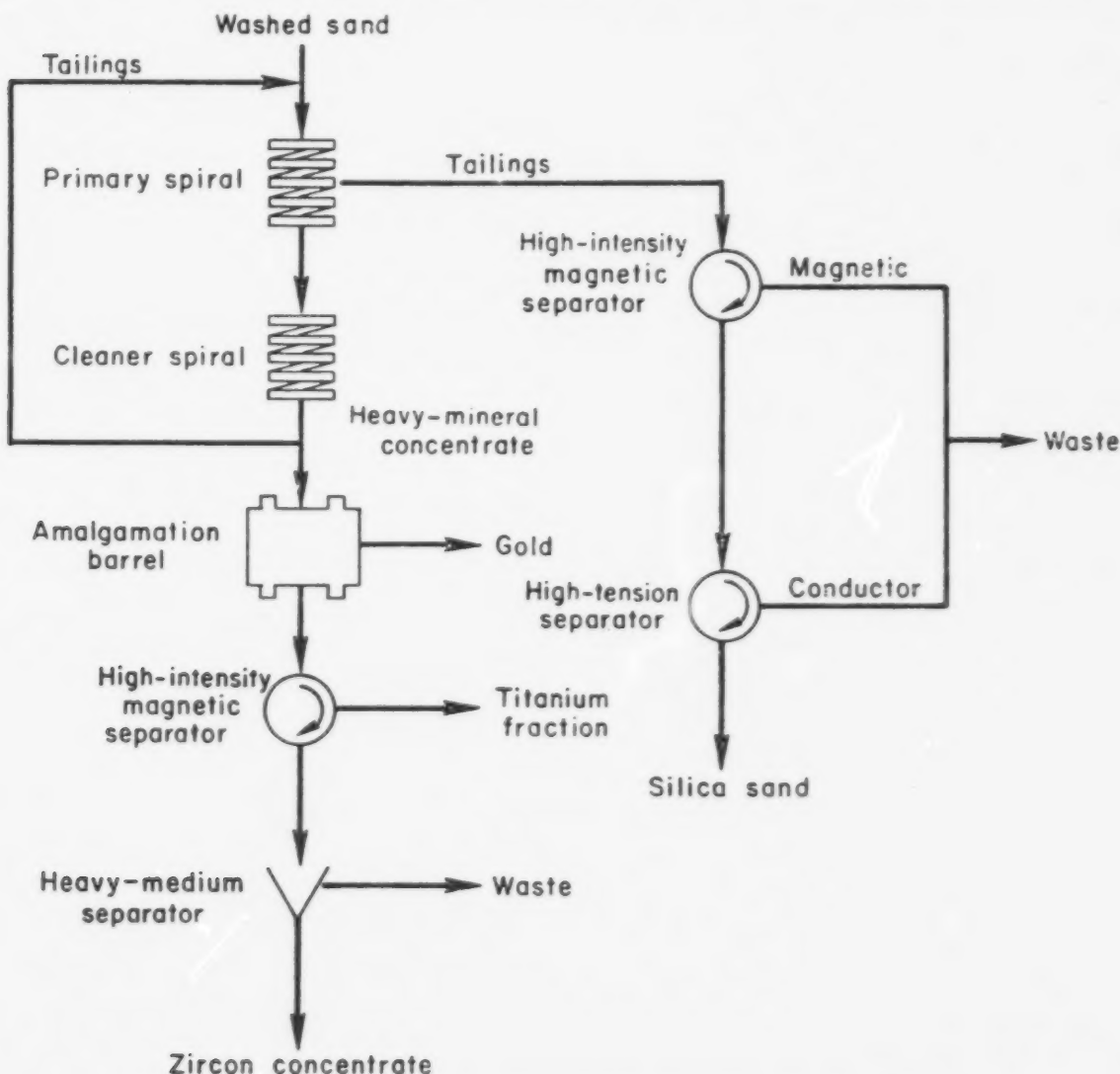


FIGURE 5. - Sequence for processing Yuba Goldfields jig concentrate.

weight-percent: magnetite, 0.2; zoned magnetite, 3 to 6; homogeneous magnetite, 3 to 16; and ilmenite, 31. The chromite grains showed a wide range of chromite content, ranging from 8 to 35 wt-pct. The ilmenite and zircon grains were totally liberated. This complex association indicated it would be difficult to separate the titaniferous and chromiferous minerals from one another and from the magnetite.

The processing sequence for fractionating the jig concentrate is shown in figure 5. The concentrate was fractionated by low-intensity magnetic separation to yield a magnetite fraction containing 67 pct of the feed material. The magnetite product had the following analysis, in weight-percent: Fe_2O_3 , 95; TiO_2 , 3.7; Cr_2O_3 , 1.9; and ZrSiO_4 , 0.1. The magnetite product contained 80 pct of the Fe_2O_3 , 55 pct of the Cr_2O_3 , and 2% pct of the TiO_2 in the jig concentrate.

Additional fractionation of the nonmagnetic fraction with the high-intensity magnetic and high-tension separators resulted in 80-pct recovery of the zircon in a product containing 63 wt-pct ZrSiO_4 . The separation of chromite from ilmenite in the high-intensity magnetic and high-tension conductor fractions was unsatisfactory.

DISCUSSION AND CONCLUSIONS

The occurrence of heavy minerals in materials handled by sand and gravel operations in northern California is widespread. The major minerals present are magnetite and ilmenite. In some localities, platinum-group metals, chromite, and zircon also occur in significant quantities. Recovery of 90 pct of the heavy minerals in bulk concentrates with an assay up to 90 wt-pct heavy minerals was achieved with a Humphreys spiral concentrator. Individual magnetite, ilmenite, and zircon concentrates were prepared by further treatments with low-intensity magnetic, high-intensity magnetic, high-tension, and heavy-medium separations.

Successful recovery of byproduct minerals will depend on the development of markets for the mineral concentrates and the incorporation of high-capacity concentrating equipment into the sand-washing circuit of the plants to prepare heavy-mineral concentrates. Equipment such as the Reichert cone or Cleveland jig with low initial and operating costs could be utilized. A plant utilizing relatively high-cost equipment to produce marketable mineral concentrates could be built in a central location to treat heavy-mineral concentrates obtained from several individual sand and gravel operations.

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Silica

B.W. BOYD

Silica production in Canada peaked in 1979 and has been in decline since then. The greatest impact was in Ontario where the closing of Inco Limited's smelter at Copper Cliff at mid-year 1982 eliminated their requirement for 'own make' smelter flux. Indusmin Limited, the largest producer of silica in Ontario, also suffered a severe reduction in sales so that shipments in 1982 were less than 50 per cent of the 1979 level. For Canada as a whole, shipments fell by 24 per cent over the three years.

Imports and exports of silica sand were lower in 1982 than in 1981 as total consumption in North America was reduced.

CANADIAN SCENE

Newfoundland. Dunville Mining Company Limited, a subsidiary of ERCO Industries Limited, continued to produce silica from a quarry at Villa Marie with no significant changes in their 1982 operations.

Nova Scotia. Nova Scotia Sand and Gravel Limited processed silica sand suitable for sand-blasting, glass, fibreglass and filter sands, from their plant in Shubenacadie. Most of the product was marketed in the four Atlantic provinces. Crushing facilities for beneficiation of sand for flint glass were completed in 1982. Sales in 1982 were down by a large margin and at least one former customer went bankrupt due to the recession.

New Brunswick. Chaleur Silica Ltd. continued to quarry sandstone at Bass River. In September of 1981, an extension on the washing plant was completed and sales improved in 1982 with shipments to new customers. A drilling program initiated in 1982 proved up new reserves of high quality silica sand.

Quebec. Indusmin Limited continued to produce from their St. Donat and St. Canut operations. According to Indusmin's Annual Report for 1982, sales and revenues were lower than in 1981 because of reduced

requirements from the glass industry and a strike at the plant of a major customer.

Baskatong Quartz Inc. operated 2 high-purity silica deposits in 1982, one near Le Petit Lac Malbaie in Charlevoix County and the other at St. Ludger in Frontenac County. The material is supplied to the SKW Canada Inc. ferrosilicon plant at Bécancour.

Armand Sicotte & Sons Limited produced coarse grade silica from their quarry near Ste-Clotilde. The company is considering penetration of glass and sand-blasting markets in northeastern United States.

The Union Carbide Canada Limited quartzitic sandstone quarry at Melocheville, Beauharnois County, was not operated during 1982. The metallurgical plants at Beauharnois and Cincoctimi were supplied from inventory and other producers.

Sable de Silice Crémazie Inc. took over operations of Montreal Silica Mines Ltd. and Usinage de Silice Champlain Limitée in March 1982. Unconsolidated Pleistocene sands near Ormstown provide feed for its washing and screening plant.

Ontario. Indusmin Limited continued to quarry a high-grade silica deposit on Badgeley Island in Georgian Bay and to operate their grinding and processing plant at Midland. Sales of excess fines increased in 1982 as new markets for this material were found. The company's exploration efforts in the Badgeley Island area located further reserves of high quality quartzite.

The Comet Quartz Limited property near Madawaska in the Algonquin Park area did not produce in 1982. The company considers it a high-purity quartz deposit with potential for the cultured quartz market and for the solar grade silicon industry.

B-Mac Silicon Aggregates Ltd. produced sand for foundries and for sand-blasting from their quarry at Bracebridge.

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TABLE 1. CANADA, SILICA PRODUCTION AND TRADE, 1981 AND 1982

	1981		1982P	
	(tonnes)	(\$)	(tonnes)	(\$)
Production, quartz and silica sand				
By province				
Quebec	694 000	12,950,000	706 000	13,781,000
Ontario	901 000	10,969,000	482 000	8,292,000
Alberta	..	3,173,000	..	3,088,000
Manitoba	198 000	2,284,000	164 000	2,688,000
Nova Scotia	..	2,334,000	..	1,401,000
New Brunswick	..	1,000,000	..	1,400,000
Saskatchewan	142 000	1,169,000	97 000	1,049,000
Newfoundland	..	768,000	..	1,632,000
British Columbia	..	46,000	..	36,000
Total	2 238 000	34,693,000	1 797 000	33,367,000
By use				
Glass and fiberglass	489 000	12,542,000	..	..
Flux	837 000	4,054,000	..	..
Ferrosilicon	339 000	3,193,000	..	..
Other uses ¹	573 000	14,904,000	..	..
Total	2 238 000	34,693,000	1 797 000	33,367,000
Imports				
Silica sand				
United States	1 142 801	18,467,000	788 468	15,475,000
United Kingdom	79	3,000	-	-
Other countries	-	-	300	120,000
Total	1 142 880	18,470,000	788 768	15,595,000
Stilex and crystallized quartz				
United States	251	319,000	229	265,000
Japan	-	-	1	1,000
West Germany	-	-	10	15,000
Brazil	-	-	1	1,000
Total	251	319,000	241	282,000
Firebrick and similar shapes, silica				
Japan	9 646	4,489,000	19	10,000
United States	3 679	2,189,000	2 564	2,021,000
France	106	133,000	219	254,000
West Germany	175	130,000	52	49,000
Other countries	156	146,000	110	72,000
Total	13 762	7,087,000	2 984	2,406,000
Exports				
Quartzite				
United States	119 347	1,107,000	65 314	566,000
Other countries	-	-	19	2,000
Total	119 347	1,107,000	65 333	568,000

Source: Statistics Canada; Energy, Mines and Resources Canada.

¹ Includes foundry use, sand blasting, silica brick, concrete products, chemical manufacture, building products and silicon carbide.

P Preliminary; - Nil; .. Not available.

TABLE 2. CANADA, SILICA PRODUCTION AND TRADE, 1970, 1975, 1978-82

Year	Production	Imports		Exports	Consumption
	Quartz and Silica Sand	Silica Sand	Silex or Crystallized Quartz (tonnes)	Firebrick and Similar Shapes	Quartzite and Silica Sand
1970	2 937 498	1 176 199	186	2 020	3 979 305
1975	2 491 715	1 044 160	1 550	18 818	3 510 818
1978	2 245 136	1 242 444	1 955	6 948	2 987 736
1979	2 368 497	1 651 890	1 259	4 896	3 611 815 ^r
1980	2 252 000	1 200 237	281	4 775	4 512 637
1981	2 238 000	1 142 880	251	13 762	3 983 751
1982P	1 797 000	788 768	241	2 984	..

Sources: Statistics Canada; Energy, Mines and Resources Canada.
P Preliminary; .. Not available; ^r Revised.

Manitoba. Steel Brothers Canada Ltd. continued to operate one of the purest deposits of silicon dioxide in North America, at Black Island in Lake Winnipeg. Production volume decreased again in 1982 reflecting the drop in consumption by the glass industry. Markets are mainly in western Canada but shallow inroads are being made in the United States market. No major changes were made in plant facilities in 1982 and the company remained fully operational throughout the year.

Alberta. Sil Silica, now a division of Strathcona Resource Industries Ltd., quarried Pleistocene dune sands at Bruderheim, 65 km northeast of Edmonton. The company remained operational in 1982 but production was affected by lower demand in the housing and oil industries.

British Columbia. Outside of Golden, Mountain Minerals Co. Ltd. processed friable Mt. Wilson quartzite to produce a glass grade silica sand. Coarser material was sold for silicon carbide use. Near Nicholson, south of Golden, a massive quartzite of the same unit was quarried by B. Miller Inc. and exported to Washington state. Contech Enterprises Ltd. worked a quartz vein near Chase, east of Kamloops, also for the export market.

On a smaller scale, International Marble & Stone Company Ltd. in Sirdar and Pacific Silica Products of Osyoos produced crushed and sized silica products.

TABLE 3. CANADA, ESTIMATED CONSUMPTION OF SILICA, BY INDUSTRIES, 1980 AND 1981

	1980	1981
	(tonnes)	
Foundry sand	1 366 152 ^r	1 085 481
Glass manufacture (including glass fibre)	968 019	951 442
Smelter flux ¹	1 192 868 ^r	837 203
Refractory brick		
mixes, cements	512 416	359 163
Artificial abrasives	130 461	125 706
Metallurgical	67 812	143 447
Chemicals	38 603	39 430
Gypsum products	8 850	2 314
Concrete products	63 254	211 608
Fertilizer, stock		
poultry feed	4 172	3 982
Other ²	160 030	223 975
Total	4 512 637 ^r	3 983 751

¹ Producers' shipments of quartz and silica for flux purposes. ² Includes asbestos products, ceramic products, frits and enamels, paper and paper products, roofing and other minor uses.
^r Revised.

investigations of promising silica deposits in Manitoba, stimulation of interest in several deposits in eastern Ontario, development plans for the silica sands of Îles de la Madeleine by Magdalen Silica Inc. and continuing examination of properties north of Baie Saint-Paul in Quebec by the Société québécoise d'exploration minière (SQQUEM).

TRADE

Since roughly 40 per cent of the silica produced is consumed as smelter flux, a major portion of the silica market is dependent on recovery of the nonferrous smelting industry. Amounts of silica consumed in the manufacture of glass and glass fibre, as well as in foundry sand, can be expected to increase as the markets for these products improve.

OUTLOOK

In the long term, growth should be possible as research and technological advances are made in the fields of fibre optics, solar grade silicon and quartz culture.

TARIFFS

CANADA

Item No.		British Preferential	Most Favoured Nation	General	General Preferential			
29500-1	Ganister and sand	free	free	free	free			
29700-1	Silex or crystallized quartz, ground or unground	free	free	free	free			
UNITED STATES								
513.14	Sand, other		free					
514.91	Quartzite, whether or not manufactured		free					
523.11	Silica, not specially provided for.		free					
			1982 1983 1984 1985 1986 1987					
			€ per long ton					
513.11	Sand containing 95% or more silica, and not more than 0.6% of oxide of iron		16	12	9	6	3	free

Sources: The Customs Tariff and Commodities Index, January 1982, Revenue Canada; Tariff Schedules of the United States Annotated 1982, USITC Publication 1200; U.S. Federal Register Vol. 44, No. 241.

st). The chief source was Australia. Metals, alloys, and rare earth oxides were imported from Brazil, China, France, the USSR, the UK, and other countries. Total value of imported concentrate was \$1.5 million, while refined products was \$15.8 million.

Planned Operations

Marathon Gold Corp. announced that it would produce monazite and xenotime concentrates as byproducts of placer gold mining at properties near Craig, CO. Rhone-Poulenc Chemicals of France announced its intention to purchase 4 to 8 kt (4400 to 8800 st) of these concentrates annually.

Williams Strategic Metals plans to extract rare earth- and thorium-bearing apatite from iron ore tailings near Mineville, NY. Beginning in 1985, its operation is expected to produce 1 kt (1100 st) of REO yearly. Significant new resources of rare earths were identified in the Poços de Caldas region of Brazil, and Guangxi, China. ■

Salt

S. J. Lefond and C. Jacoby, Consultants

US salt production increased in 1984 an estimated 18%, from 33 Mt (36 million st) in 1983 to 39 Mt (43 million st). The value of production increased from \$597 million in 1983 to an estimated \$670 million last year. An additional 6 Mt (6.6 million st) were imported from Canada, 38%; Mexico, 28%; Bahama Islands, 15%; Chile, 5%; and others, 14%.

While 44 companies operated 83 plants in 15 states, the 10 largest accounted for more than 75% of the salt used or sold in the US. Three states, Louisiana, Texas, and New York, produce more than 70% of the domestic output of salt.

Worldwide production of salt was 190 Mt (209 million st). Peoples Republic of China, USSR, Canada, India, and West Germany are also major producers of salt.

The chemical industry was again the major consumer (55%) of salt, which is used to produce chlorine and caustic soda. About 20% of US production was used to de-ice highways. The remaining 25% was used in paper and food products, agriculture, water treatment, metal production, and several minor applications.

Morton Thiokol closed its evap-

orated salt plant in Maryville, MI, during the fourth quarter of 1984, idling about 233 workers. Morton cited the decline in the national use of table salt as the reason. Other sources credit the weak market to large imported tonnages of evaporated salt from Holland.

Diamond Crystal Salt Co., in an attempt to replace the loss it sustained by the disastrous flooding of its Jefferson Island mine in

Average price per ton of salt produced in US by type

	1983	1984
Evaporated	88.54	90.40
Rock	15.65	16.52
Solar	24.05	23.84
Highway Use	12.11	12.66

Louisiana in 1980, is acquiring the American Salt Co., from General Host Corp.

This acquisition, reportedly costing \$40 million, provides Diamond with a source of rock salt from a mine in Lyons, LA. The mine is said to have a capacity of 500 kt/a (551,000 stpy) of rock salt with a companion evaporating plant that has a capacity of 300 kt/a (331,000 stpy). The acquisition also includes a small solar evaporation operation at Grantsville, UT. This will give Diamond Crystal annual sales totaling about \$110 to \$120 million.

The Detroit mine that International Salt Co. reported last year as being "mothballed," was abandoned as a rock salt mine. This mine had been producing 1.3 Mt (1.5 million st) annually from under the city of Detroit. It was in operation for more than 80 years.

On Jan. 31, 1984, Cargill Inc., closed its Belle Isle mine. Production from Cote Blanc Avery Island, Weeks Island, and Caribbean salt will replace the lost production of Belle Isle.

Rock salt facilities that have been lost or abandoned recently include Cary's mine at Winnefield, LA; Jefferson Island mine, 1980; Detroit mine, 1983; and Belle Isle, 1984. All these mines were major producers. ■

Silica Sand

W. F. Pennfield

Production and consumption of industrial silica improved in 1984 beyond most companies' expectations. Sales of this industrial min-

eral expanded rapidly in the first half of the year.

Preliminary estimates are that 26 Mt (29 million st) tons of silica sand were sold or used at a value of \$370 million. This is an increase of nearly 2.7 Mt (3 million st), or 11.2% in production and \$40 million, (12.3%) in value. The US Bureau of Mines' estimate is based on a survey. It may be high in view of the decline in the rate of growth of the GNP in the fourth quarter.

Production in 1984 is expected to be the highest since 1981. The value of products sold increased 12%. This almost imperceptible change could reflect product mix. But, in all probability, it is a direct result of excess productive capacity controlling prices.

Markets

Most major markets improved with the exception of glass containers. Earlier in the decade, leveraged buyouts reduced the number of glass companies and operating plants. In 1984 alone five manufacturing plants closed or announced closings. Aging plants and equipment, excess capacity, and competitive products contributed to the market decline. Glass containers represents the largest market for industrial silica — about 26%.

Glass container manufacturing is expected to decline about 1% per year over the next three years. Plastic containers are expected to grow at the rate of 5% per year.

Flat glass improved in 1984. Of the 39 tanks in the US, about 37 were operating throughout the year. The first major expansion since 1981 was completed this year. A second should be complete by third quarter 1985, bringing the total to 40 tanks. Total production increased by an estimated 4%, as production of domestic cars increased 993,000 units, or 14.6%.

Another user of flat glass, the construction industry, also improved, with housing starts up 4.1%. Economic recovery was also noted in the foundry industry with the number of castings up 23.8%. Expectations for 1985 are for an increase of 14.7%.

Prices

According to government statistics, the average value of shipments was estimated at \$14/t (\$12.76 per st), a 0.9% improvement over 1983. Contributing significantly to this marginal change was the value of shipments to glass

container manufacturers. Price declines were registered in all sections of the US, except California where the selling price remained unchanged.

Foundry sand prices also declined selectively, compared to 1983, but to a lesser extent than glass sand prices. Again, the decline in selling prices reflects the major market forces of supply and demand, as well as a deflationary economy. Industrial sand prices are expected to lag the producer price index change.

Owens-Illinois continued to sell off its industrial sand plants. This year, it was its Mission Viejo facility, first opened in January 1976. The purchaser was Oglebay Norton. The new facility will be known as California Silica Products Co.

Martin-Marietta Corp. completed the sale of its last industrial sand plant at Wedron, IL. The company signed a lease/option with the Wedron management and Best Sands Co. of Chardon, OH. Pennsylvania Glass Sand has begun a \$6.6-million modernization and expansion at four of its six ground sand plants. ■

Soda Ash

J. P. Searls, US Bureau of Mines

US Production

The US soda ash industry showed a slight decline in production of an estimated 7.6 Mt (8.4 million st) in 1984. Year-end stocks were relatively unchanged from those of 1983. The producing industry operated at 75% of nameplate capacity.

US apparent consumption declined only 1% below that of 1983 to an estimated 6.2 Mt (6.8 million st). However, exports were 3% below those of 1983. The only end use that did not rise with the general improvement in the US and European economies was the bottled drink container industry, which continued its switch from glass to plastic (polyethylene terephthalate or PET) bottles in sizes larger than 1 L (0.26 gal).

In 1984, the US exported an estimated 1.4 Mt (1.6 million st) of soda ash to 50 countries. US trona producers remained the low-cost soda ash producers in the world

soda ash market vis-a-vis the synthetic producers.

The European Economic Community (EEC) Commission announced provisional duties on imports of US soda ash into member countries. The combined production and transportation costs for US natural soda ash delivered to Europe were apparently less than European synthetic soda ash production costs. The reorganized US exporting (Webb-Pomerene) association was renamed the American Natural Soda Ash Corp. (ANSAC).

The glass industry, primarily the container glass industry, is the

The European Economic Commission announced duties on US soda ash imports into member countries. US delivered costs are less than European delivered costs.

end user with the poorest growth outlook for the soda ash industry. In much of Europe, the use of recycled (cullet) glass is encouraged. In parts of the US, the use of both recycled and reusable bottles is encouraged. The US Bureau of Alcohol, Tobacco, and Firearms has allowed the sale of liquor in PET bottles.

A possible growth market, internationally, may be in substituting soda ash for caustic soda in the pulp and paper industry, because caustic soda supply has been controlled by the demand for chlorine. FMC Corp. is in the forefront of an attempt by the US soda ash industry to enter the environmental protection market with a flue gas desulfurization process for coal-fired powerplants.

In the US, FMC received approval from the Wyoming Environmental Quality Control Council to attempt solution mining of trona. It is assumed that the process will be integrated into the present plant without adding any new capacity to the US industry. International Minerals & Chemical Corp., which is not a soda ash producer, is building a dry bulk marine terminal, in Texas City, TX, that is designed to handle soda ash, among other commodities.

Foreign Production

A group of Australian investors composed of Denison Resources, Adelaide Brighton Cement, and Poseidon Ltd., began a feasibility study of producing soda ash, bicarbonate of soda, and caustic soda from underground brines in the Denison Trough of central Queensland. The caustic soda will probably be intended for the world's largest alumina plant at the port city of Gladstone, Queensland. Denison Trough is at least 800 km (500 miles) by rail — including a lift over the Great Dividing Range — from Gladstone.

Imperial Chemical Industries (ICI) Australia plant at Osborne will continue soda ash, chlorine, and bicarbonate of soda production but will drop caustic soda production.

During 1984, the sole Australian soda ash producer, ICI Australia, raised its prices, and a large Australian consumer purchased some US soda ash. ICI Australia called for a dumping investigation, expressing concern with the US rail rates applied to soda ash shipments from Wyoming to ocean ports for export.

A proposed Thai-ASEAN (Association of Southeast Asian Nations) synthetic soda ash plant on the Gulf of Thailand was rejected in the summer of 1984, but resurrected late in the year in a scaled-down version. Thai soda ash production would replace imports from Japan, Africa, and North America. It would reportedly save about \$20 million in import costs and provide up to \$60 million in export earnings. In the same region, two separate Indonesian groups have each proposed a synthetic soda ash plant in Indonesia of possibly 180 kt/a (200,000 stpy) capacity.

Prices

The domestic price of soda ash remained at about \$99/t (\$90 per st), minus a \$12/t (\$11 per st) Temporary Voluntary Allowance (TVA) throughout much of the year. The domestic producers tried during much of the year to reduce the size of the TVA. But overcapacity in the industry made such moves difficult. In a reported European price change, ICI Ltd. raised its prices in Britain in August by £77 to £122/t (£7 to £111 per st) for light soda ash and £124/t (£113 per st) for heavy soda ash. ■